12/01/97 JC561 U.S. PTO

A

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.

UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	RFX-349	Total Pages	59
First Named Inventor or Application Identifier			
William P. Rowland, et al.			
Express Mail Label No.	EM361200180US		

APPLICATION ELEMENTS
See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: **Assistant Commissioner for Patents**
Box Patent Application
Washington, DC 20231

1. [ ] Fee Transmittal Form
   (Submit an original, and a duplicate for fee processing)
2. [X] Specification [Total Pages 29]
   (preferred arrangement set forth below)
   - Descriptive title of the Invention
   - Cross References to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to Microfiche Appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings *(if filed)*
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
3. [X] Drawing(s) *(35 USC 113)* [Total Sheets 29]
4. Oath or Declaration /POA [Total Pages]
   a. [ ] Newly executed (original or copy)
   b. [ ] Copy from a prior application (37 CFR 1.63(d))
   (for continuation/divisional with Box 17 completed)
   [Note Box 5 below]
   i. [ ] DELETION OF INVENTOR(S)
   Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
5. [ ] Incorporation By Reference *(useable if Box 4b is checked)*
   The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6. [ ] Microfiche Computer Program *(Appendix)*
7. Nucleotide and/or Amino Acid Sequence Submission
   (if applicable, all necessary)
   a. [ ] Computer Readable Copy
   b. [ ] Paper Copy (identical to computer copy)
   c. [ ] Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

8. [ ] Assignment Papers (cover sheet & document(s))
9. [ ] 37 CFR 3.73(b) Statement *(when there is an assignee)* [ ] Power of Attorney
10. [ ] English Translation Document *(if applicable)*
11. [X] Information Disclosure Statement (IDS)/PTO-1449 [X] Copies of IDS Citations
12. [ ] Preliminary Amendment
13. [ ] Return Receipt Postcard (MPEP 503)
    (Should be specifically itemized)
14. [ ] Small Entity Statement(s) [ ] Statement filed in prior application, Status still proper and desired
15. [ ] Certified Copy of Priority Document(s)
    (if foreign priority is claimed)
16. [ ] Other: ....

17. If a **CONTINUING APPLICATION**, *check appropriate box and supply the requisite information:*
[ ] Continuation [ ] Divisional [ ] Continuation-in-part (CIP) of prior application No: _______/__________

18. CORRESPONDENCE ADDRESS

[ ] *Customer Number or Bar Code Label* *(Insert Customer No. or Attach bar code label here)* or [X] *Correspondence address below*

NAME	Leo R. Reynolds, Esq.				
	HAMILTON, BROOK, SMITH & REYNOLDS, P.C.				
ADDRESS	Two Militia Drive				
CITY	Lexington	STATE	MA	ZIP CODE	02173
COUNTRY	USA	TELEPHONE	(781)861-6240	FAX	(781)861-9540

Signature Robert T. Conway
Robert T. Conway, Reg. No. 33,859

Date: December 1, 1997

08980835 120197

#3

VERIFIED STATEMENT CLAIMING SMALL ENTITY STATUS (37 CFR 1.9(f) & 1.27(c))-SMALL BUSINESS CONCERN

DOCKET NUMBER: RFX-349

O I P E
MAR 3 0 1998
JC41
PATENT & TRADEMARK OFFICE

Applicant or Patentee: William P. Rowland and Robert B. Nilsen
Serial or Patent No.: 08/980,885
Filed or Issued: December 1, 1997
Title: MINIATURE MICRO PRISM RETROREFLECTOR

I hereby declare that I am
[ ] the owner of the small business concern identified below:
[X] an official of the small business concern empowered to act on behalf of the concern identified below:

NAME OF SMALL BUSINESS CONCERN Reflexite Corporation
ADDRESS OF SMALL BUSINESS CONCERN 120 Darling Drive
Avon, Connecticut 06001-4217

I hereby declare that the above identified small business concern qualifies as a small business concern as defined in 13 CFR 121.12 and reproduced in 37 CFR 1.9(d), for purposes of paying reduced fees to the United States Patent and Trademark Office. in that the number of employees of the concern, including those of its affiliates, does not exceed 500 persons. For purposes of this statement, (1) the number of employees of the business concern is the average over the previous fiscal year of the concern of the persons employed on a full-time, part-time or temporary basis during each of the pay periods of the fiscal year, and (2) concerns are affiliates of each other when either, directly or indirectly, one concern controls or has the power to control the other, or a third party or parties controls or has the power to control both.

I hereby declare that rights under contract or law have been conveyed to and remain with the small business concern identified above with regard to the invention described in:

[ ] the specification filed herewith with title as listed above.
[X] the application identified above.
[ ] the patent identified above.

If the rights held by the above identified small business concern are not exclusive, each individual, concern or organization having rights in the invention must file separate verified statements averring to their status as small entities, and no rights to the invention are held by any person, other than the inventor, who would not qualify as an independent inventor under 37 CFR 1.9(c) if that person made the invention, or by any concern which would not qualify as a small business concern under 37 CFR 1.9(d), or a nonprofit organization under 37 CFR 1.9(e).

Each person, concern or organization having any rights in the invention is listed below:
[X] no such person, concern, or organization exists.
[ ] each such person, concern or organization is listed below.

Separate verified statements are required from each named person, concern, or organization having rights to the invention averring to their status as small entities. (37 CFR 1.27)

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b))

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

NAME OF PERSON SIGNING Robert B. Nilsen

TITLE OF PERSON IF OTHER THAN OWNER Vice President of Technology

ADDRESS OF PERSON SIGNING 120 Darling Drive, Avon, Connecticut 06001-4217

SIGNATURE Robert B. Nilsen DATE Jan 27, 1998

K:\LREYNOLD\LRR43\RFX349.VS

RFX349.APL
LRR41
LRR/mrf
12/01/97

Date: 12/1/97 Express Mail Label No. EM361200180US

Inventors: William P. Rowland and Robert B. Nilsen

Attorney's Docket No.: RFX-349

MINIATURE MICRO PRISM RETROREFLECTOR

BACKGROUND OF THE INVENTION

This invention pertains to retroreflective materials and most particularly retroreflective material using micro cube corner prisms as the retroreflective elements.

Retroreflective materials are employed for various safety and decorative purposes. Particularly, these materials are useful at night time when visibility is important under low light conditions. With perfect retroreflective materials, light rays are reflected towards a light source in a substantially parallel path along an axis of retroreflectively. For many applications, perfect retroreflectivity is not required. Rather, a compromise is required in which a cone of divergent light is retroreflected which permits enough light to strike the viewer's eye, yet not so much that the intensity of the reflective light at the viewer's eye is unduly diminished. Under circumstances where the only source of illumination is the headlights of an automobile on an unlit road, the ability to retroreflect such a cone of divergence to the eye of the driver is important for safety reasons.

Many types of retroreflective material exist for various purposes. These retroreflective materials can be

used as reflective tapes and patches for clothing, such as vests and belts. Also, retroreflective bands can be used on posts, barrels, traffic cone collars, highway signs, warning reflectors, etc. Retroreflective material may be comprised of arrays of randomly oriented micron diameter spheres or close packed cube-corner (prismatic) arrays.

Cube-corner or prismatic retroreflectors are described in U.S. Pat. No. 3,712,706, issued to Stamm (Jan. 23, 1973). Generally, the prisms are made by forming a master negative die on a flat surface of a metal plate or other suitable material. To form the cube-corners, three series of parallel equidistance intersecting V-shaped grooves 60 degrees apart are inscribed in the flat plate. The die is then used as a mold to form a transparent cube-corner array which is then processed into sheets of retroreflective material.

When the groove angle is 70 degrees, 31 minutes, 43.6 seconds, the angle formed by the intersection of two cube faces (the dihedral angle) is 90 degrees and the incident light is reflected back to the source. For automobile headlight reflectors, the dihedral angle is changed slightly so that the incidental light is reflected non-orthogonally towards the driver instead of the source.

Preferably, the retroreflected light from the vehicle headlights should be returned in a cone wide enough to encompass the eye of the vehicle's driver (this angle is referred to as the angle of observation).

At long distances the cone of light need only encompass two-tenths of a degree, but as the distance is decreased and/or as the distance from the head lamps to the eyes of the driver increase (as in the case of the driver of a large truck verses that of a sports car) then the

cone of light should be increased to five-tenths or even one degree.

Many attempts have been made to keep the intensity of the retroreflected light uniform over this larger cone. Changing the dihedral angle of the cube corner prism will spread this cone of light, but in a star shaped pattern that is not uniform.

Diffraction of the light (see Stamm 3,712,706) by the small effective aperture of the cube corner prisms spreads the light, but again in a non-uniform manner with hot spots and nulls in decreasing intensity as the angle of the cone increases.

Mild diffusers have been tried such as texturing the front surface of the material or incorporating light scattering pigments or light refracting particles in a top coating on the front surface or in a top film. This technique scatters or redirects the light over much larger angles beyond the viewing cone so that much of the light is lost.

SUMMARY OF THE INVENTION

Diffraction scattering is most useful but has several drawbacks. Relatively small prisms in the size of .006" to .12" on centers which are air backed will diffract the light out into a cone of 0.5°, but the light pattern is not uniform. Furthermore, air backed prisms are troublesome and expensive. The reflecting faces of the prisms must be protected from contact with all other materials by constructing air cells in the backing materials. However, when the same size prisms are metalized, the diffraction is much reduced and will not sufficiently encompass the 0.5° angle.

We have found that if the cube corner prism pattern is ruled with prisms spaced in the range of .001" to .003" on center, and most preferably .002" on center, and the resulting prisms are metalized, the retroreflected cone of light is spread out to include a 0.5° observation angle, and the intensity throughout the area is very uniform despite substantial change of the dihedral angle. This result is believed to occur because for very small prisms (0.001" to 0.003"), diffraction effects spread or diverge the light over wide observation angles, and therefore a change in the dihedral angles of the prisms, such as may occur during master generation or product manufacturing, will have less impact on the change in the light distribution. The six overlapping return beams caused by diffraction (see FIG. 4 of U.S. 5,171,624 issued December 15, 1992, and incorporated in its entirety herein by reference) are diverging much more in the very small metallized prisms, so that as the dihedral angles change and the six beams move apart the central portion of the entire light distribution will retain light longer (at a greater dihedral angle) than with larger prisms, *i.e.*, in excess of .003".

The extreme cases are a very large prisms that return six well collimated beams that overlap each other versus metalized very small prisms that return very divergent beams that overlap each other. A substantial dihedral angle change will cause the beams retroreflected from the large prism to completely separate from each other leaving a dark area in the center of the return beam. The same dihedral angle change in the small prisms will cause the beam spread to be the same, but because of the divergence caused by diffraction, the edges of the beams will still be overlapping, and a dark area will not occur.

The result will be a much safer product, because a dihedral angle change will not leave dark areas in the retroreflected light distribution.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view of a retroreflective structure in accordance with the invention.

FIG. 2 is a plan view of the structure of FIG. 1 as viewed from the prism side.

FIG. 3 is a plan view of several sheets of prism array tiles of the invention parqueted together.

FIG. 4 is a sectional view as in FIG. 1 showing the array of FIG. 1 embedded in an adhesive.

FIG. 5 is an enlarged view of a portion of the section of FIG. 1 showing the optional creation of flats at the prism intersections.

FIG. 6 is a photo of the retroreflected light intensity pattern for a 6 mil. pitch prism array with metal backing.

FIG. 7 is a photo of the retroreflected light intensity pattern for a 6 mil. pitch prism array with air backing.

FIG. 8 is a photo of the retroreflected light intensity pattern for a 2 mil. (.002") pitch prism array with metal backing.

FIG. 9 is a photo of the retroreflected light intensity pattern for a 2 mil. (.002") pitch prism array with air backing.

FIGs. 10-12 are brightness polar plots at a 0.10 observation angle of a metal backed .0055" prism array as the dihedral angle is changed in 1.5 minute increments.

FIGs. 13-15 are brightness polar plots at a 0.33 observation angle of a metal backed .0055" prism array as the dihedral angle is changed in 1.5 minute increments.

FIGs. 16-18 are brightness polar plots at a 0.10 observation angle of a metal backed 0.002" prism array as the dihedral angle is changed in 1.5 minute increments.

FIGs. 19-21 are brightness polar plots at a 33° observation angle of a metal backed 0.002" prism array as the dihedral angle is changed in 1.5 minute increments.

FIG. 22A is a computer-generated theoretical diffraction pattern plot of a metal backed 0.002 pitch prism array.

FIG. 22B is an intensity plot versus angle of observation for a metal backed 0.002 pitch prism array.

FIG. 22C is a computer-generated three-dimensional surface plot of a metal backed 0.002 pitch prism array.

FIG. 23A is a computer-generated theoretical diffraction pattern plot of a metal backed 0.006 pitch prism array.

FIG. 23B is an intensity plot versus angle of observation for a metal backed 0.006 pitch prism array.

FIG. 23C is a computer-generated three-dimensional surface plot of a metal backed 0.006 pitch prism array.

FIG. 24 is a plot of specific intensity per unit area (SIA) versus prism pitch size.

FIG. 25A is a two-dimensional isometric photograph of a graph of the retroreflected light distribution from a 2 mil. pitch metal backed prism array.

FIG. 25B is a three-dimensional plot of the retroreflected light from a 2 mil. pitch metal backed prism array.

FIG. 25C is an X-Y profile of the retroreflected light distribution from a 2 mil. pitch metal backed prism array.

FIG. 25D is a polar plot of retroreflected light distribution in comparison to an ideal diffuser surface for a 2 mil. pitch metal backed prism array.

FIG. 26A is a two-dimensional colored isometric photograph of a graph of the retroreflected light distribution from a 1 mil. pitch metal backed prism array.

FIG. 26B is a three-dimensional plot of the retroreflected light from a 1 mil. pitch metal backed prism array.

FIG. 26C is an X-Y profile of the retroreflected light distribution from a 1 mil. pitch metal backed prism array.

FIG. 26D is a polar plot of retroreflected light distribution in comparison to an ideal diffuser surface for a 1 mil. pitch metal backed prism array.

FIG. 27A is a two-dimensional isometric photograph of a graph of the retroreflected light distribution from a 0.5 mil. pitch metal backed prism array.

FIG. 27B is a three-dimensional plot of the retroreflected light from a 0.5 mil. pitch metal backed prism array.

FIG. 27C is an X-Y profile of the retroreflected light distribution from a 0.5 mil. pitch metal backed prism array.

FIG. 27D is a polar plot of retroreflected light distribution in comparison to an ideal diffuser surface for a 0.5 mil. pitch metal backed prism array.

FIG. 28A is a two-dimensional isometric photograph of a graph of the retroreflected light distribution from a 0.24 mil. pitch metal backed prism array.

FIG. 28B is a three-dimensional plot of the retroreflected light from a 0.24 mil. pitch metal backed prism array.

FIG. 28C is an X-Y profile of the retroreflected light distribution from a 0.24 mil. pitch metal backed prism array.

FIG. 28D is a polar plot of retroreflected light distribution in comparison to an ideal diffuser surface for a 0.24 mil. pitch metal backed prism array.

FIG. 29A is a two-dimensional isometric photograph of a graph of the retroreflected light distribution from a 0.1 mil. pitch metal backed prism array.

FIG. 29B is a three-dimensional plot of the retroreflected light from a 0.1 mil. pitch metal backed prism array.

FIG. 29C is an X-Y profile of the retroreflected light distribution from a 0.1 mil. pitch metal backed prism array.

FIG. 29D is a polar plot of retroreflected light distribution in comparison to an ideal diffuser surface for a 0.1 mil. pitch metal backed prism array.

FIG. 30A is a two-dimensional isometric photograph of a graph of the retroreflected light distribution from a 2 x 550 nm. pitch metal backed prism array.

FIG. 30B is a three-dimensional plot of the retroreflected light from a 2 x 550 nm. pitch metal backed prism array.

FIG. 30C is an X-Y profile of the retroreflected light distribution from a 2 x 550 nm. pitch metal backed prism array.

FIG. 30D is a polar plot of retroreflected light distribution in comparison to an ideal diffuser surface for a 2 x 550 nm. pitch metal backed prism array.

FIG. 31A is a two-dimensional isometric photograph of a graph of the retroreflected light distribution from a 550 nm. pitch metal backed prism array.

FIG. 31B is a three-dimensional plot of the retroreflected light from a 550 nm. pitch metal backed prism array.

FIG. 31C is an X-Y profile of the retroreflected light distribution from a 550 nm. pitch metal backed prism array.

FIG. 31D is a polar plot of retroreflected light distribution in comparison to an ideal diffuser surface for a 550 nm. pitch metal backed prism array.

FIG. 32 is a polar plot of the retroreflected light intensity from a 0.0017" pitch metalized prism array at a 0.10° observation angle with a -1.04 DAD as averaged over three samples.

FIG. 33 is a plot as in FIG. 32 with a DAD of +1.55.

FIG. 34 is a plot as in FIGs. 32 and 33 with a DAD of +3.67.

FIG. 35 is a plot as in FIGs. 32-34 with a DAD of +2.28.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

DETAILED DESCRIPTION OF THE INVENTION

The features and other details of the method and apparatus of the invention will now be more particularly described with reference to the accompanying drawings and pointed out in the claims. The same numeral present in different figures represents the same item. It will be

understood that the particular embodiments of the invention are shown by way of illustration and not as limitations of the invention. The principal features of this invention can be employed in various embodiments without departing from the scope of the invention.

One embodiment of the invention, as shown in the cross-sectional view of FIG. 1 is retroreflective structure 10. Retroreflective structure 10 may be generally formed of a base film or substrate 12 and a retroreflective cube-corner prism array 14.

Film 12 may typically comprise a plastic material such as a polymer, and preferably an elastomeric polymer, which can recover substantially its original shape after a deforming force has been removed. Preferably, the elastomeric polymer is transparent to visible light and is composed of a polymer, such as polyurethane, polyisobutylene, polyester, polybutadiene, polyvinyl chloride or polyvinylidene chloride. Alternatively, the polymer can be a copolymer or terpolymer, such as poly(ethylene-propylene), poly(styrene-butadiene), poly(vinyl acetate-vinyl chloride) and poly(ethylene-vinyl acetate).

The array 14 consists of retroreflective cube-corner prism elements 20. The prism array 14 has a window or aperture side 16 and three-sided facet side 18. The prisms 20 of the prism array 14 are also formed of a transparent plastic, such as a polymer that has a high modulus of elasticity. The polymer may be selected from a wide variety of polymers, including urethane, acrylic acid esters, cellulose esters, ethylenically unsaturated nitriles, hard epoxy acrylates, etc. Other polymers may include polycarbonates, polyesters and polyolefins, acrylated silanes, hard polyester urethane acrylates.

Preferably, the array elements 20 are cast in a prismatic mold with a monomer or oligomer. Polymerization is typically initiated by ultraviolet radiation.

The array 14 is preferably formed by casting or molding the plastic material of the array in a metal or plastic mold (not shown) which is ruled with a diamond tool. The rulings extend in three intersecting planes 24, 26 and 28 (FIG. 2), spaced 60° apart and (as previously mentioned) to the extent the groove angle is 70 degrees, 31 minutes and 43.6 seconds, the angle formed by the intersection of the two groove faces (the dihedral angle) will be 90 degrees. Note, however, since a single mold is reused to cast many generations of arrays, it is likely that this dihedral angle will vary slightly from array to array.

Next, facets 18 of the prisms 20 are provided with a reflective coating 26, preferably by depositing a metal film on the surface (during or after the array is removed from the mold). Typically the coating is formed by sputtering or vacuum depositing aluminum, silver or gold.

In accordance with the invention, the center-to-center spacing (or pitch = p) between the apices of adjacent prisms is in the range of 0.0005" to 0.003", with a preferred range between 0.001" and 0.003", and most preferably about 0.002".

The array 10 shown in FIGs. 1 and 2 may be replicated several times and seamed together to form tiles of arrays 10 as in FIG. 3. Before or after tiling, the facet side of the arrays may be coated with an adhesive 44 as in FIG. 4, and bonded to a metal panel (not shown).

Such very small prisms have some disadvantages and many advantages. The main negative is that it is very difficult to rule an array of .002" on center prisms over a

large area, as the ruling cutting diamond wears out. Also, due to the many strokes required, the time on the ruling machine is excessive. Also, vibration, temperature and humidity variation come into play to a greater extent because of the time required to cut the master. So one must be content to use small ruled areas and parquet or tile replicas to make a large area mold. Alternatively, using the process described in U.S. 5,558,740 issued September 24, 1996 (incorporated in its entirety herein by reference), the several prism arrays may be formed on several drums and seamed together.

We have found, however, that the advantages of very small prisms are many and important. The smaller the prism the less it is stressed. Stress caused during prism formation by the polymerization of the oligomer is reduced as each .002" prism contains 27 times less oligomer than the prior art .006" pitch size prisms. Stress caused by distortion of the substrate 12 is now divided into nine times as many segments, and the adhesive 44 used to bond the metalized prism surface to a backing panel can be made three times as thin. Also, a very desirable feature is that the total thickness T (FIG. 4) which includes the adhesive 26, top film 12 and any coating (not shown) can be reduced by about .002". Such a very thin product with the increased number of prisms and resulting prism intersections increases the flexibility of the product. The optional addition of micro textured flats F of about 40 to 60 millionths in width (FIG. 5) at the increased number of prism intersections (there are approximately 500,000 prisms per square inch) or the optional addition of textured windows as in U.S. Patent 5,565,151, issued October 15, 1996 (incorporated herein by reference in its entirety) can be used to create a very uniform high Cap Y

(whiteness) product. The thin finished product is less susceptible to removal from various substrates by power washing or abrasion because of the very thin edge produced. The product can be made to be frangible, so that as the product breaks apart prism by prism, less retroreflective area will be lost. Printing of patterns on the prism front faces or the top film or coating surface will result in less retroreflected light loss because the edges of the pattern will effect more prisms but overall less active retroreflecting area.

An important feature of the invention is the use of metalized prisms in combination with the less than .006" on centers prism size. Conventional prior art air backed prisms reflect at the prism facets by internal reflection. This is, when light goes from a high index material, plastic or glass to an air interface and the angle of incidence is greater than the so-called critical angle, the light is internally reflected. Also, the polarization of the light is rotated 90° at each of the three internally reflecting faces.

This phase change, created by the polarization rotation, has the effect of breaking up the single aperture (the base of the prism receiving the exiting light) into six smaller apertures. Reference: *Applied Optics*, 35(22), August 1, 1996. B.C. Park, T.B. Eom and M.S. Chung. The smaller the aperture the greater divergence of the light that is diffracted. The result is that .006" pitch air backed prisms spread the light by diffraction over a fairly wide cone angle.

Metalized prisms reflect at each of the prism reflecting faces by specular reflection, and the polarization of the light is rotated 180°. With a retroreflective cube corner prism, the light is reflected

sequentially off the three faces. The full 180° rotation of all of the light causes the light to have a phase change which causes less interference than the phase changes that occur in the air backed cube corner prisms.

When the prism is metalized, no effective polarization rotation occurs and the base of the prism acts as a single aperture which is six times as large as that of the equivalent pitch air backed prism. The result is that in the metalized prisms the diffraction phenomenon is greatly reduced and, as a result the light intensity is concentrated in the center or first maxima.

In order to create the same diffraction scattering phenomenon of an air backed prism, the metalized prism must therefore be six times smaller than the air backed prism. A metalized prism of .00256" on centers will diffraction scatter the light to the same extent as an air backed prism .006" on centers.

The smaller the prism pitch, the greater is the diffraction spreading of the returned retroreflected light. Therefore, air backed prisms in the size range of .006" to .012" will diffract enough to scatter the retroreflected cone of light wide enough to satisfy the .5° angle of observation performance required for highway use.

However, the same size prisms with metal backing will perform only marginally at the .5° angle of observation. Conversely, we have found that microprisms in the order of .002" on center when air backed diffract the light so widely that they will not meet the .5° requirement. However, when they are metalized, as disclosed herein, they return the ideal pattern of light for highway use.

Also, by using metalized very small or "micro-micro" size prisms, the disadvantages of air backed large prisms are avoided, *i.e.*, extra layers and thickness and sealing

to provide the air cells, the thickness caused by the height of the prisms and the stiffer substrates required to support the larger prisms.

EXPERIMENTAL DATA OBTAINED USING STANDARD TEST METHODS FOR RETROREFLECTIVE SHEETING

The following terms have the following meanings as used herein:

"entrance angle β" is the angle between the illumination axis and the retroreflector axis;

"observation angle α" is the angle between the axes of the incident beam and the observed (reflected) beam (*in retroreflection*, between the illumination axis and the observation axis);

"orientation angle" or the "rotation angle ϵ" is in retroreflection, the angle indicating the orientation of the specimen when it is rotated about the retroreflector axis; and

"orientation free," means that the intensity of the retroreflected light is substantially constant over a range of orientation angles.

FIGs. 6-9 are photographs which show the retroreflected light intensity pattern for various pitch size prism arrays. FIG. 6 shows the pattern for a 6 mil. (.0055") pitch prism array with metal backing, and FIG. 7 is a comparable pattern for the same pitch size prism with air backing. FIGs. 8 and 9 show the metal (FIG. 8) and air backed (FIG. 9) intensity patterns for a 2 mil. (.002") pitch size prism array, respectively. Note that the metalized .002" pitch prism array intensity pattern is slightly larger than the air backed .0055" pitch prism array intensity pattern and much larger than the metalized

.0055" pitch prism array intensity pattern. The metalized .002" pitch array gives excellent retroreflective performance at all important observation, orientation and entrance angles.

The polar plots of FIGs. 10-18 illustrate the change in brightness of various metal backed prism array pitch sizes at a .10 observation angle as the dihedral angle is changed in increments of 1.5 minutes. Note that the entrance angles are as indicated at the X and Y axis, and the orientation angles are plotted clockwise above the perimeter with 90° located at 12 o’clock. FIGs. 10, 11 and 12 are polar plots of a .0055" pitch prism array; FIGs. 13-15 are plots of a 0.55" pitch size array, and FIGs. 16-18 are plots for a .002" pitch size array.

The plots of FIGs. 19-21 are for a .002" pitch size, metal backed prism array at a 33° observation angle with dihedral angle changes in 1.5 minute increments.

Note how the brightness changes at the center of the .0055" pitch prism array charts (FIGs. 10-12) as the dihedral angle changes and how the brightness does not change at the center of the .002" pitch prism array charts (FIGs. 16-21) as the dihedral angle changes. The smaller prism retroreflected brightness is much less sensitive to changes in the dihedral angle because of the increased diffraction spreading of light that takes place. At the .33 observation angle (FIGs. 13-15) the shape of the .0055" pitch prism array pattern is also changing because the measurements at this angle are in an area near the edge of the diffracted beam central maxima. A larger prism will show an even greater change with dihedral angle.

FIGs. 22A-22C and FIGs. 23A-23C are computer plots of the theoretical reflected light intensity distribution of a metal backed .002" pitch prism array and a metal backed

.006 pitch prism array, respectively. The A plots show the observation angle diffraction pattern for zero° to 360° orientation angles, the B plots show the intensity (candles per lux per m^2) versus observation angle, and the C plots are three-dimensional surface plots of observation angle α on the X and Y axis for zero° to 360° orientation angles ϵ.

These plots clearly show the much improved uniformity of the diffraction pattern in the smaller prism. The retroreflected light is very uniform out beyond the 1.0 degree observation angle.

FIG. 24 is a plot of SIA versus P taken at an incident wavelength of 550 nm of light for prisms having an index of refraction n of 1.58 which shows the rate of loss of retroreflected light as the pitch of the prism becomes very small. The smallest pitch shown is one wavelength in width. Below a pitch size of about .00024" (6μ), the retroreflected light values are very low and are not suitable for most retroreflective applications. At a size of .00048" (12μ) a graphics quality retroreflective product could be made. Allowing for features, such as machined in windows, steps or textured or printed patterns, to add whiteness (Cap Y) a .0010" (25μ) pitch prism is more suitable for graphics.

The numerical tables of Chart 1 (at the end of the text) show the actual SIA values at observation angles (2 to 20 degrees) and at orientation angles (0 to 180 degrees) for the various pitch prism sizes.

FIGs. 25A-25D through FIGs. 31A-31D show the actual retroreflected light distribution for the various size metal backed pitch prisms. The upper left graph or "A" plots are of a two-dimensional isometric photo plot of the retroreflected light distribution in which the orientation angle is the circular coordinate around the perimeter of

the plot. The lower left graph, the "B" plots, are three dimensional plots of the retroreflected light distribution versus observation angle on the X and Y axis. The upper right (or "C" plots) show the x and y profile of the retroreflected light distribution versus observation angle on the X axis. The lower right polar charts (or "D" plots) show the retroreflected light distribution in comparison to an ideal diffuser (scattering) surface. The large oval, dotted line plot within the "D" plots is that of an ideal scattering surface as calculated from the cosine law which is used to describe scattering surfaces.

One can see that when the prism pitch is on the order of one wavelength of light, the surface acts very much like an ideal diffuser across the entire plus or minus twenty degree range shown. Note that in the case of most interest, *i.e.*, the .1 to 2.0 degree range, a prism pitch of .00024" (6μ) has a very flat retroreflected light distribution, and the magnitude of the retroreflected light is not sufficient to be useful in safety or graphics applications and can for all practical purposes be considered a scattering surface.

TABLE I.

Material index n= 1.58 Incident wavelength 0.55μ

	0	30	60	90	120	150	180
p= 0.55 μ	Diffraction pattern center 0.277094				x_dim= 28	num_el= 12	
2	0.276009	0.268360	0.267451	0.276112	0.267451	0.268360	0.276009
3	0.272773	0.272773	0.273183	0.273183	0.273183	0.272773	0.272773
5	0.263800	0.275019	0.275019	0.265045	0.275040	0.275040	0.263800
10	0.240213	0.227189	0.231435	0.243547	0.231310	0.227059	0.240213
15	0.192449	0.214612	0.217402	0.199442	0.217883	0.215108	0.192450
20	0.153400	0.106732	0.117616	0.162724	0.117479	0.106562	0.153400
p= 1.1μ	Diffraction pattern center 1.10921				x_dim= 28	num_el= 25	
2	1.09191	1.08934	1.08811	1.09355	1.08794	1.08917	1.09191
3	1.04138	1.03748	1.04339	1.04770	1.04371	1.03781	1.04138
5	0.937052	1.00770	1.01039	0.952433	1.01133	1.00864	0.937052
10	0.614060	0.529966	0.567030	0.651382	0.568781	0.532007	0.614061
15	0.244590	0.253804	0.276966	0.287903	0.280723	0.258252	0.244590
20	0.0447142	0.0187576	0.0331774	0.0684727	0.0334652	0.0196932	0.0447143
p= 2.54μ	Diffraction pattern center 5.91538				x_dim= 28	num_el= 58	
2	5.35856	5.53286	5.56440	5.40976	5.56610	5.53460	5.35856
3	4.27033	4.30684	4.38934	4.40861	4.40047	4.31847	4.27034
5	2.44668	2.67441	2.78656	2.67714	2.80657	2.69629	2.44668
10	0.03221	0.0221600	0.0465547	0.0861019	0.0485138	0.0255519	0.0322188
15	0.05372	0.102494	0.0596130	0.106152	0.0647632	0.101192	0.0537201
20	0.02329	0.00616553	0.0095105	0.0158121	0.00723417	0.00863740	0.0232964
p= 6.0 μ	Diffraction pattern center 30.6670				x_dim= 56	num_el= 34	
2	17.6844	22.7109	22.7174	17.6940	22.7150	22.7089	17.6845
3	5.74838	4.07407	4.07466	5.73605	4.07915	4.07461	5.74841
5	0.093497	0.233042	0.230440	0.213802	0.231730	0.232854	0.093497
10	0.197556	0.0357433	0.163038	0.0353620	0.163220	0.0367408	0.197554
15	0.053959	0.0002405	0.0504714	0.0001631	0.0496691	0.0002982	0.053959
20	0.0543252	0.0004467	0.0106888	0.00269081	0.0106856	0.0004583	0.054325
p= 12.00μ	Diffraction pattern center 122.680				x_dim= 112	num_el= 69	
2	8.97002	16.2979	16.3003	8.91879	16.3183	16.3001	8.97018
3	1.28402	2.32242	1.44851	2.34774	1.44456	2.32920	1.28403
5	0.77322	0.0890128	0.928461	0.140298	0.928813	0.0924924	0.773214
10	0.217322	0.004792	0.0955855	0.0107643	0.0967986	0.00564159	0.217323
15	0.0156515	0.002203	0.0566172	0.000111476	0.0531123	0.00249192	0.0156516
20	0.0245323	0.000230	0.0421930	0.000562044	0.0437915	0.00117474	0.0245322
p= 25.0μ	Diffraction pattern center 532.480				x_dim= 112	num_el= 145	
2	1.35084	0.473851	3.13965	1.99163	3.12382	0.476578	1.35084
3	0.611894	0.0439605	1.58550	0.0148991	1.57822	0.0419281	0.611891
5	0.219538	0.0250036	0.461071	0.0196173	0.448551	0.0235029	0.219547
10	0.159382	0.0015656	0.0252273	0.00264892	0.0334400	0.00249989	0.159384
15	0.077203	2.95e-005	0.0118687	0.000189794	0.0119416	0.000480	0.0772034
20	0.049299	0.000261	0.00529208	0.000438401	0.00584164	0.0004874	0.0492996

	0	30	60	90	120	150	180
p=	50.0μ	Diffraction pattern center		2113.43		x_dim= 224	num_el= 145
2	3.77091	0.0661667	1.53038	0.193074	1.59519	0.0601697	3.77101
3	1.98520	0.0451807	0.827603	0.0335625	0.880270	0.0444823	1.98519
5	0.404825	0.009065	0.373326	0.0110170	0.433263	0.00836996	0.404839
10	0.174884	0.000798	0.0353489	0.00113079	0.0310147	0.0003498	0.174883
15	0.0610804	0.0008053	0.0002712	9.524e-005	7.899e-005	0.0002379	0.061078
20	0.0058884	0.0003731	0.0003102	5.685e-005	0.001329	3.97e-005	0.005888

The following Tables 2A and 2B and FIGs. 32-35 illustrate that the DAD (dihedral angle deviation) has a much smaller influence on the brightness of small pitch prisms relative to large pitch prisms.

The tables are for a .0017" and a .002" metal backed pitch prism, respectively, and the FIGs. 32-35 are for a .0017" metal backed pitch prism array and show that a DAD range from -1.04 minutes to 3.67 minutes causes virtually no change in the retroreflected brightness of the samples. The same dihedral angle variation in larger pitch prisms (.0060" pitch) would cause a very large change (on the order of 50%) in the retroreflected brightness.

The advantage of the small prism is the very uniform retroreflected brightness at all important entrance, orientation and observation angles and the additional manufacturing process latitude that will be present for manufacturing tooling (molds) and the product replicated from the molds. This result combined with the thinner prism will allow running at much higher manufacturing speeds.

TABLE 2A
.0017" Pitch

	Dihedral Angle	1st Generation		3rd Generation		5th Generation		7th Generation	
		-1.04	-1.04	1.55	1.55	3.67	3.67	2.28	2.28
Observation Angle	Entrance Angle (B1)	-180	-90	-180	-90	-180	-90	-180	-90
0.10	5	567.93	563.27	544.17	542.63	545.40	538.10	546.70	538.57
	10	532.63	526.47	511.67	506.53	508.00	503.27	513.57	505.37
	20	416.20	399.70	404.07	382.73	390.37	378.93	396.93	382.53
	30	268.23	238.50	253.87	227.40	246.17	224.93	253.20	228.90
	40	135.33	111.47	128.57	105.77	123.53	104.97	124.53	107.23
	45	84.82	68.90	81.32	65.12	76.75	64.83	78.10	66.71
	50	53.63	39.83	51.98	37.35	48.15	37.41	47.55	38.72
	60	21.21	9.63	19.00	8.78	16.41	9.14	15.97	9.76
0.20	5	541.67	522.97	520.93	504.37	516.23	502.10	518.47	502.43
	10	510.43	490.80	493.17	473.13	482.87	469.20	487.93	471.20
	20	399.90	377.60	386.67	360.87	374.93	357.67	379.03	361.33
	30	256.63	229.33	246.33	219.20	235.97	216.77	244.67	220.07
	40	129.67	109.20	123.37	103.83	118.37	102.97	120.97	105.20
	45	82.65	67.92	78.17	64.18	75.47	64.06	76.57	65.87
	50	52.15	39.43	50.99	37.01	47.44	37.06	46.79	38.41
	60	20.51	9.64	19.12	8.78	16.36	9.15	15.89	9.78
0.33	5	481.50	442.00	464.93	427.30	461.00	425.03	463.13	425.50
	10	456.17	418.73	441.10	403.93	436.43	400.00	437.87	402.03
	20	361.03	329.67	349.67	316.67	338.57	313.70	342.33	315.67
	30	235.00	209.10	225.47	200.17	217.10	197.90	222.57	200.53
	40	120.20	104.00	114.10	99.05	110.33	98.02	111.93	100.02
	45	76.82	65.70	72.53	62.09	70.50	62.01	71.60	63.61
	50	49.69	38.70	47.98	36.34	44.47	36.37	44.27	37.67
	60	19.62	9.63	18.99	8.79	16.15	9.13	15.64	9.76
0.50	5	377.87	312.27	367.73	301.77	363.40	299.77	364.43	299.60
	10	362.03	299.27	351.97	290.37	347.73	287.43	348.53	287.17
	20	292.13	248.60	285.27	240.80	275.80	237.93	278.43	238.50
	30	194.53	172.43	188.67	167.30	181.20	165.13	186.03	165.63
	40	103.23	93.70	97.63	89.56	93.26	88.46	95.71	89.90
	45	66.59	61.26	63.26	58.01	60.67	57.81	62.22	59.08
	50	43.88	37.06	43.21	34.76	39.30	34.78	39.35	35.93
	60	17.39	9.56	18.51	8.68	15.37	9.00	14.74	9.64
1.00	5	88.88	32.83	91.84	33.50	90.02	31.84	86.34	30.20
	10	96.42	34.99	97.91	36.40	96.48	34.69	94.03	32.91
	20	108.73	45.07	106.73	47.23	102.90	45.79	103.73	43.24
	30	92.80	57.12	88.70	58.42	83.61	57.05	88.46	54.82
	40	53.57	51.61	50.48	50.93	46.36	49.81	49.48	49.35
	45	35.06	40.25	33.41	39.09	30.66	38.53	32.38	38.75
	50	24.44	27.99	24.65	26.72	21.59	26.53	21.51	27.07
	60	15.08	8.72	14.30	7.95	11.22	8.21	10.77	8.74

	Dihedral Angle	1st Generation		3rd Generation		5th Generation		7th Generation	
		-1.04	-1.04	1.55	1.55	3.67	3.67	2.28	2.28
Observation Angle	Entrance Angle (B1)	-180	-90	-180	-90	-180	-90	-180	-90
1.50	5	5.93	17.31	8.35	16.34	6.69	14.40	5.20	14.57
	10	9.19	13.59	11.36	12.96	10.64	11.01	9.03	11.60
	20	30.51	5.59	30.10	5.55	29.20	4.12	29.36	4.29
	30	49.76	7.12	46.37	8.68	43.41	7.53	47.78	6.50
	40	34.69	17.36	31.36	18.72	27.82	17.65	32.07	16.48
	45	20.37	18.71	18.40	19.26	15.83	18.58	18.56	18.01
	50	12.32	16.69	11.59	16.61	9.56	16.24	10.12	16.14
	60	10.01	7.15	9.58	6.62	6.77	6.80	6.56	7.16
2.00	5	14.32	16.94	12.46	15.10	11.05	14.79	11.52	16.17
	10	9.88	14.16	9.64	13.07	8.79	12.91	8.86	14.56
	20	4.84	7.83	5.51	6.72	5.36	6.83	4.71	8.29
	30	22.65	2.69	21.94	2.35	20.43	1.93	22.35	2.61
	40	27.30	3.62	24.82	4.57	21.94	3.86	25.75	3.28
	45	17.12	5.79	15.05	6.80	12.74	6.23	15.87	5.61
	50	8.92	7.65	7.37	8.25	5.96	7.85	7.17	7.42
	60	8.79	5.25	6.63	5.01	4.43	5.07	4.35	5.25

TABLE 2B
.0020" Pitch

	Dihedral Angle	3rd Generation		5th Generation		7th Generation	
		3.89/-1.3	3.89/-1.3	-1.13/-0.1	-1.13/0.1	10.59	10.59
Observation Angle	Entrance Angle (B1)	-180	-90	-180	-90	-180	-90
0.10	5	827.00	790.50	821.80	815.30	764.30	789.50
	10	757.30	748.70	770.60	765.70	788.70	745.80
	20	561.50	569.00	580.20	583.40	580.40	564.90
	30	355.40	367.60	354.70	362.30	339.60	350.30
	40	156.40	170.70	159.80	167.80	153.70	158.10
	45	95.03	103.80	97.87	102.90	91.85	96.39
	50	58.76	59.73	59.56	57.99	52.14	53.97
	60	18.25	14.11	27.80	13.49	16.06	12.34
0.20	5	735.40	727.70	751.50	755.90	696.00	720.30
	10	693.00	692.60	704.30	711.70	706.50	687.60
	20	522.60	538.40	544.20	545.20	530.80	529.70
	30	333.50	349.80	340.90	345.10	318.30	333.50
	40	148.90	165.70	157.60	161.70	146.50	153.50
	45	91.81	101.70	96.78	99.50	88.49	94.34
	50	56.83	58.74	57.72	56.92	50.74	53.08
	60	18.07	14.11	26.99	13.24	15.97	12.31
0.33	5	602.50	604.00	610.70	623.90	575.90	596.00
	10	568.60	573.00	585.50	587.30	583.60	567.40
	20	436.90	457.40	467.80	464.00	448.50	450.70
	30	284.90	299.80	295.90	299.50	274.40	291.30
	40	134.80	154.30	142.40	150.10	133.00	143.10
	45	84.51	96.65	88.91	93.98	81.44	89.65
	50	52.25	56.71	54.24	54.01	47.39	51.27
	60	17.48	13.95	25.03	12.55	15.37	12.17
0.50	5	394.50	400.70	409.40	418.40	378.10	399.40
	10	380.20	381.20	397.10	396.60	389.50	383.20
	20	308.80	321.60	336.10	333.70	320.90	321.90
	30	216.90	227.90	226.20	233.20	210.50	226.30
	40	110.40	131.10	117.40	127.90	109.30	123.40
	45	70.76	86.11	74.29	83.43	68.59	80.19
	50	45.24	52.11	47.26	49.62	41.10	47.59
	60	16.22	13.47	23.95	12.20	14.29	11.84
1.00	5	22.09	24.13	29.31	28.47	22.58	25.71
	10	33.06	25.99	38.16	31.38	35.12	28.26
	20	66.55	35.41	75.43	42.85	71.10	39.20
	30	82.76	47.29	88.76	55.94	82.82	51.77
	40	51.52	52.38	55.11	55.42	52.05	51.97
	45	32.08	43.49	35.06	45.44	32.26	42.76
	50	21.18	32.00	23.13	32.26	19.70	30.35
	60	10.58	10.86	19.89	10.17	9.26	9.80
1.50	5	18.05	28.18	16.78	23.94	17.16	27.02
	10	13.62	23.26	12.16	18.82	13.49	22.31
	20	8.43	10.06	9.50	7.34	8.60	9.83
	30	32.35	4.10	34.41	4.62	33.33	4.87
	40	33.75	9.62	34.81	12.01	34.77	10.25
	45	19.66	12.34	21.03	14.95	20.06	13.22
	50	9.84	13.17	10.99	14.77	9.21	13.22
	60	5.36	7.27	16.02	7.23	4.37	6.80
2.00	5	6.85	14.75	8.39	12.89	7.54	14.49
	10	10.80	13.06	11.18	10.86	11.91	13.11
	20	8.84	7.51	9.98	6.11	9.42	8.00
	30	6.61	3.33	8.51	2.51	7.12	3.64
	40	22.63	1.52	23.38	1.65	24.14	1.63
	45	16.67	2.09	17.34	2.91	17.37	2.38
	50	8.13	3.53	8.72	4.61	7.81	3.63
	60	3.25	3.94	14.97	4.30	1.95	3.83

EQUIVALENTS

While this invention has been particularly shown and described with references to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims. Those skilled in the art will recognize or be able to ascertain using no more than routine experimentation, many equivalents to the specific embodiments of the invention described specifically herein. Such equivalents are intended to be encompassed in the scope of the claims.

CLAIMS

We claim:

1. A retroreflective structure comprising an array of transparent prisms having a base and three facets extending therefrom to a common apex, the base of the prisms lying in a common plane, the prisms being spaced between 0.0005 inch to 0.003 inches on center with a reflective coating adhered to the facets.

2. A retroreflective structure comprising an array of transparent faceted cube corner prisms having a base and three facets extending therefrom to a common apex, the base of the prisms lying in a common plane, the prisms being spaced 0.002 inches on center with a reflective coating adhered to the facets.

3. The structure of claim 1, wherein a flat surface is provided between the base of prisms to reflect light.

4. The structure of claim 1, which includes several arrays seamed together.

5. The structure of claim 1, wherein the prisms are cube-corner prisms.

6. The structure of claim 1, wherein adjacent prisms form prism pairs in which the tips of the apices of the prism pairs are tilted with respect to one another.

7. The structure of claim 1, wherein the prisms are orientation free.

8. The structure of claim 1, wherein the light retroreflected from the structures encompasses a 0.5 degree angle of observation, uniform orientation-free cone.

9. A method of forming retroreflective sheeting comprising the steps of:
   a) forming a mold by forming three parallel sets of grooves in a body of mold material; the grooves intersecting at an angle to form a plurality of prism pairs, each prism in a pair having a base and three intersecting lateral faces which meet at an apex, and wherein the grooves between prism pairs are spaced between 0.0005 inch to 0.003 inches apart.
   b) forming said sheeting in said mold;
   c) removing the sheeting from the mold; and
   d) before or after removing, coating the lateral faces with a light reflective material to form said sheeting for reflecting a uniform orientation free cone of light which encompasses a 0.5 degree angle of observation.

10. Retroreflective sheeting formed by the method of claim 9.

11. A method of forming retroreflective sheeting comprising the steps of:
   a) providing a mold comprised of a plurality of prism pairs, spaced between 0.0005 inch and 0.003 inches on center, each prism having a base and three intersecting lateral faces which meet at an apex;

b) forming said sheeting in said mold;

c) removing said sheeting from said mold; and

d) before or after removing the sheeting coating the faces with reflective material.

12. The method of claim 10, wherein the prisms are made by forming three parallel sets of grooves spaced between 0.0005 inch to 0.003 inches apart in a body of mold material; the grooves intersecting at a dihedral angle, which dihedral angle may not be constant, and wherein the sheeting so formed will retroreflect a uniform orientation free cone of light encompassing a 0.5 degree angle of observation.

13. Retroreflective sheeting formed by the method of Claim 11.

14. A method of forming retroreflective sheeting comprising the steps of:

a) forming a mold by forming three parallel sets of grooves in a body of mold material, the grooves spaced between 0.0005 inch to 0.003 inches apart; the grooves intersecting at an angle to form a plurality of prism pairs, each prism in a pair having a base and three intersecting lateral faces which meet at an apex;

b) forming said sheeting in said mold;

c) removing the sheeting from the mold; and

d) before or after removal, coating the faces with metallic retroreflective material.

MINIATURE MICRO PRISM RETROREFLECTOR

ABSTRACT OF THE DISCLOSURE

Retroreflective sheeting for forming orientation free cones of reflected light encompassing a 0.5 degree angle of observation is formed of small metal backed cube corner prisms in an array in which the size of the prisms are in a range between 0.0005 inch to 0.003 inches on center. The array is formed by casting transparent plastic prisms in a mold formed by ruling three sets of grooves which intersect at an angle. The grooves are spaced apart in the range of 0.0005 inch to 0.003 inches on center. Before or after formation, the prisms are coated with a reflective material such as a metal.

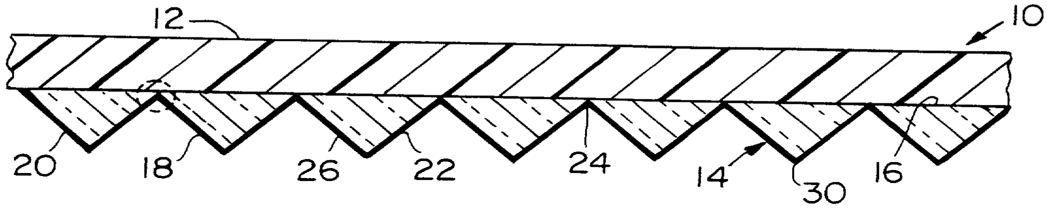


FIG. 1

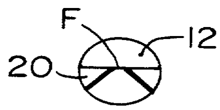


FIG. 5

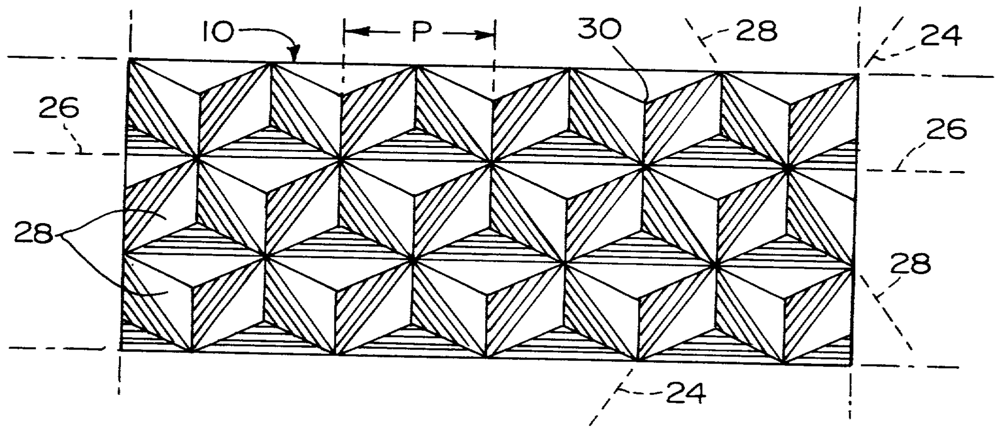


FIG. 2

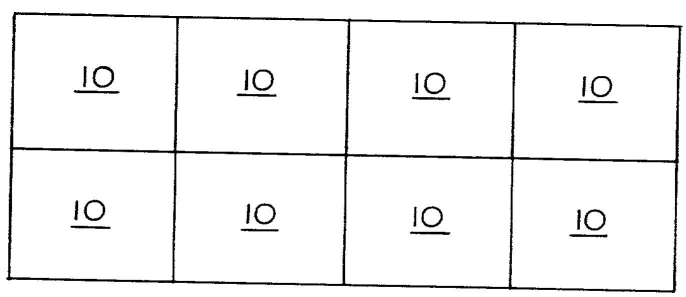


FIG. 3

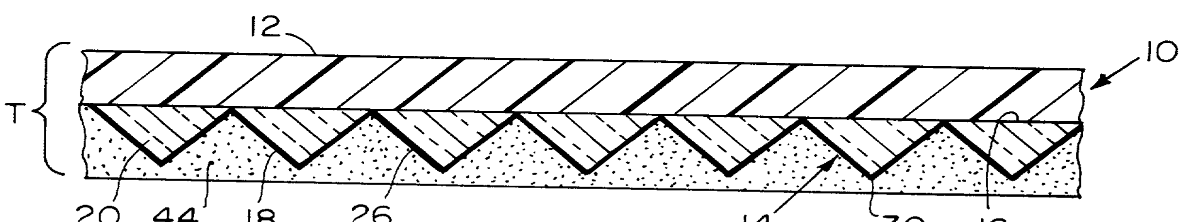


FIG. 4

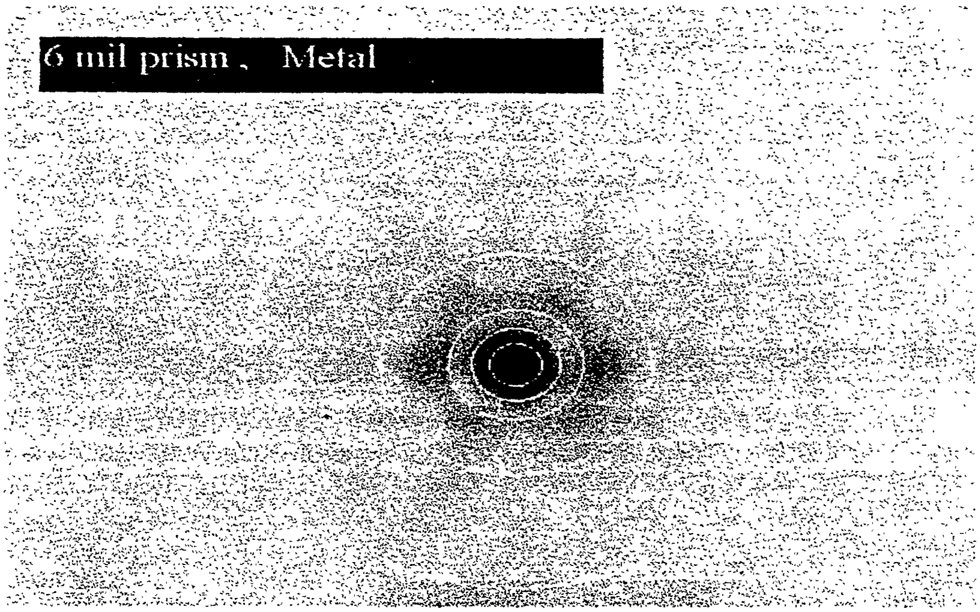


FIG. 6

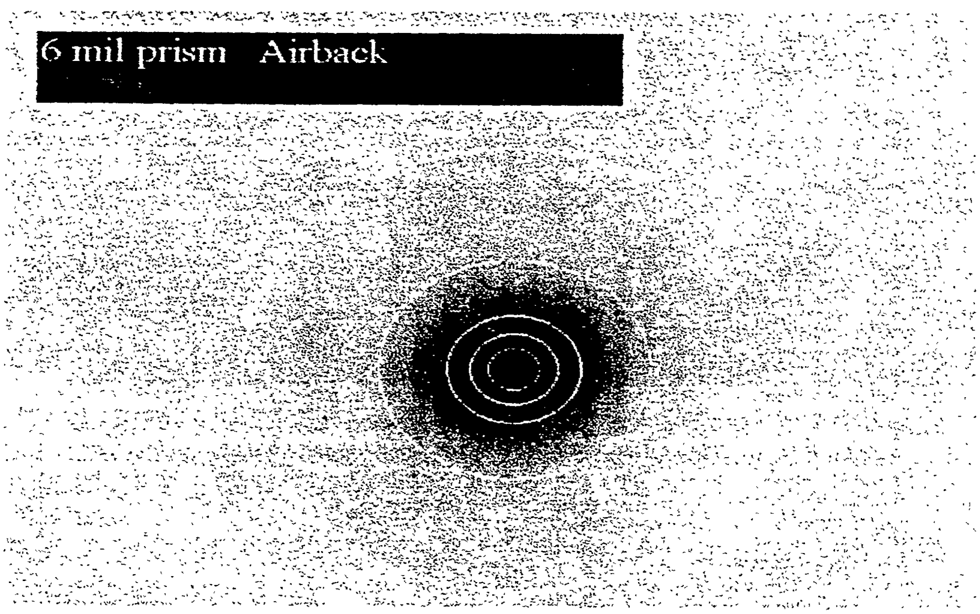


FIG. 7

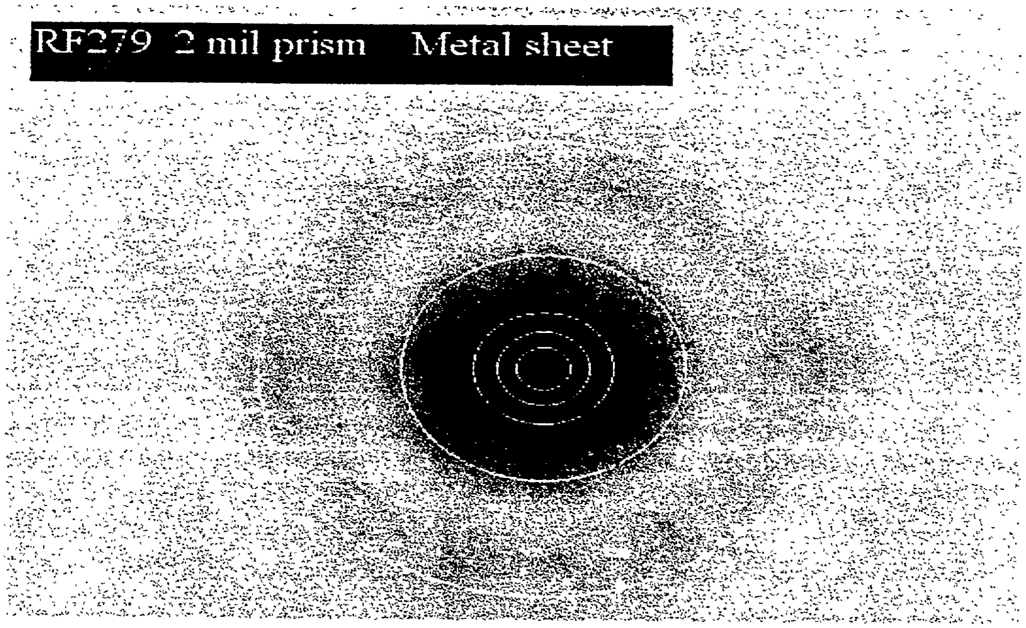


FIG. 8

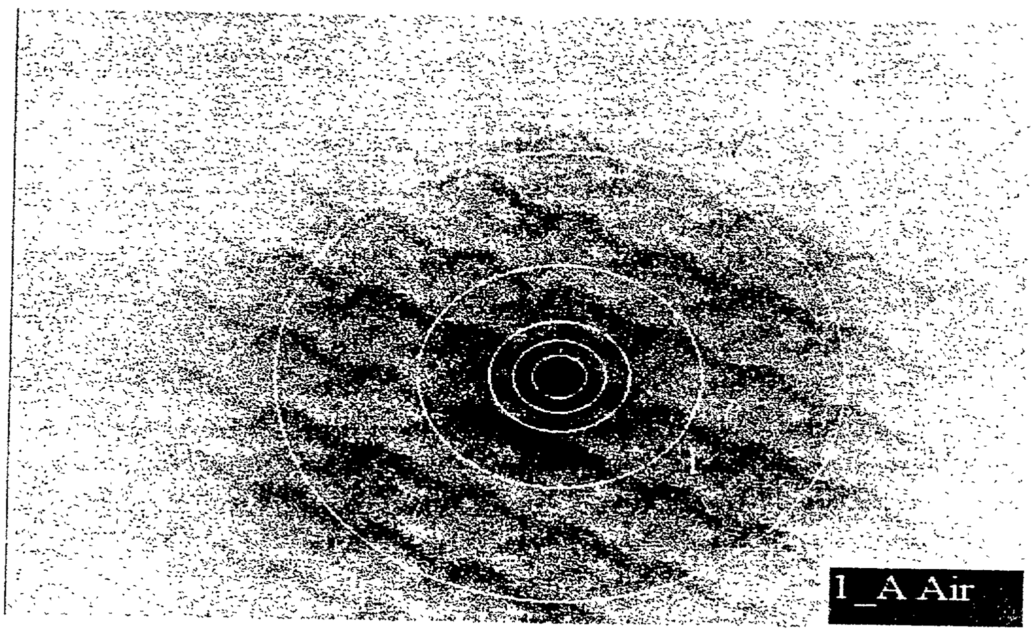


FIG. 9

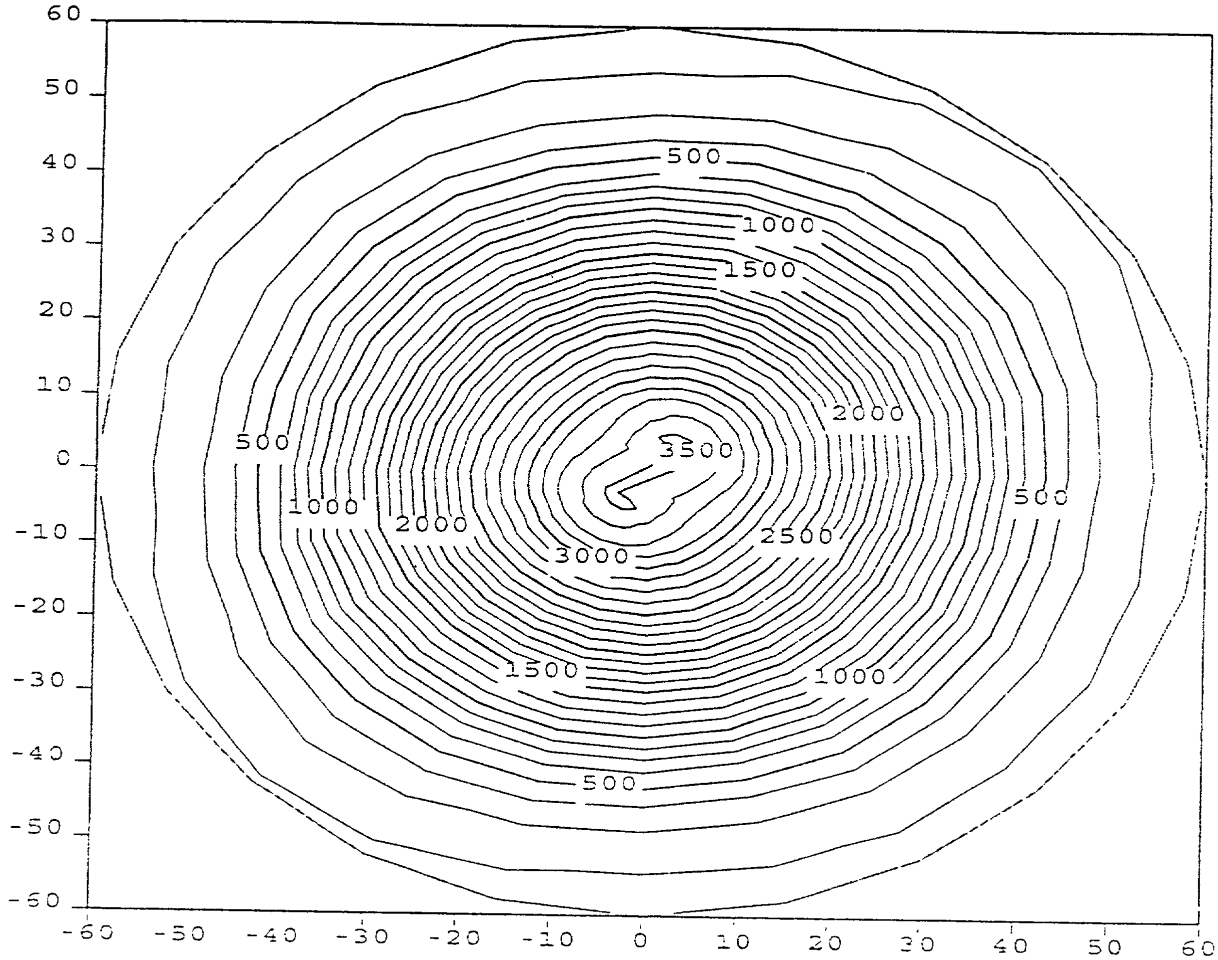

60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
500
1000
1500
2000
2500
3000
3500
500
1000
2000
500
1500
1000
500

FIG. 10

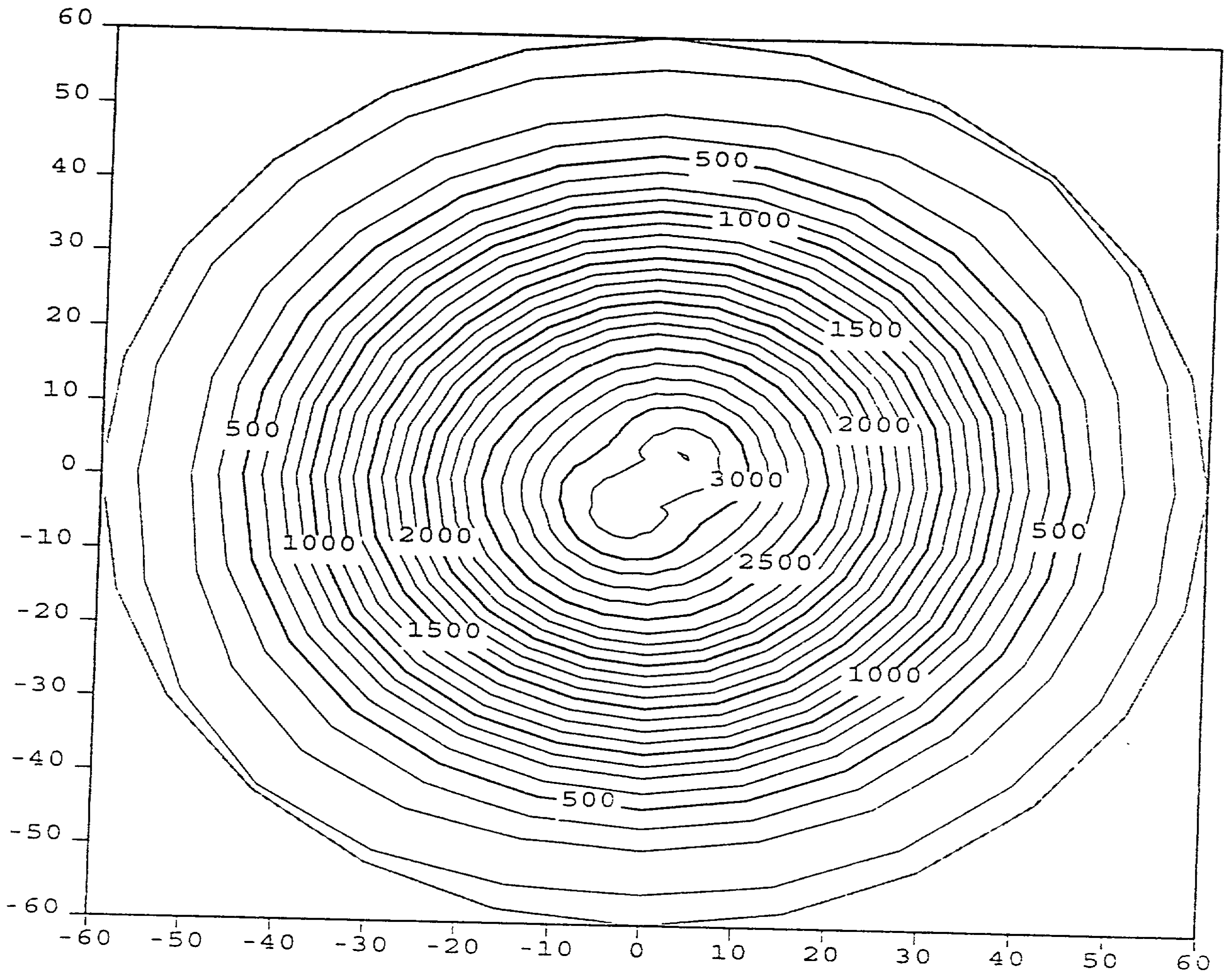


FIG. 11

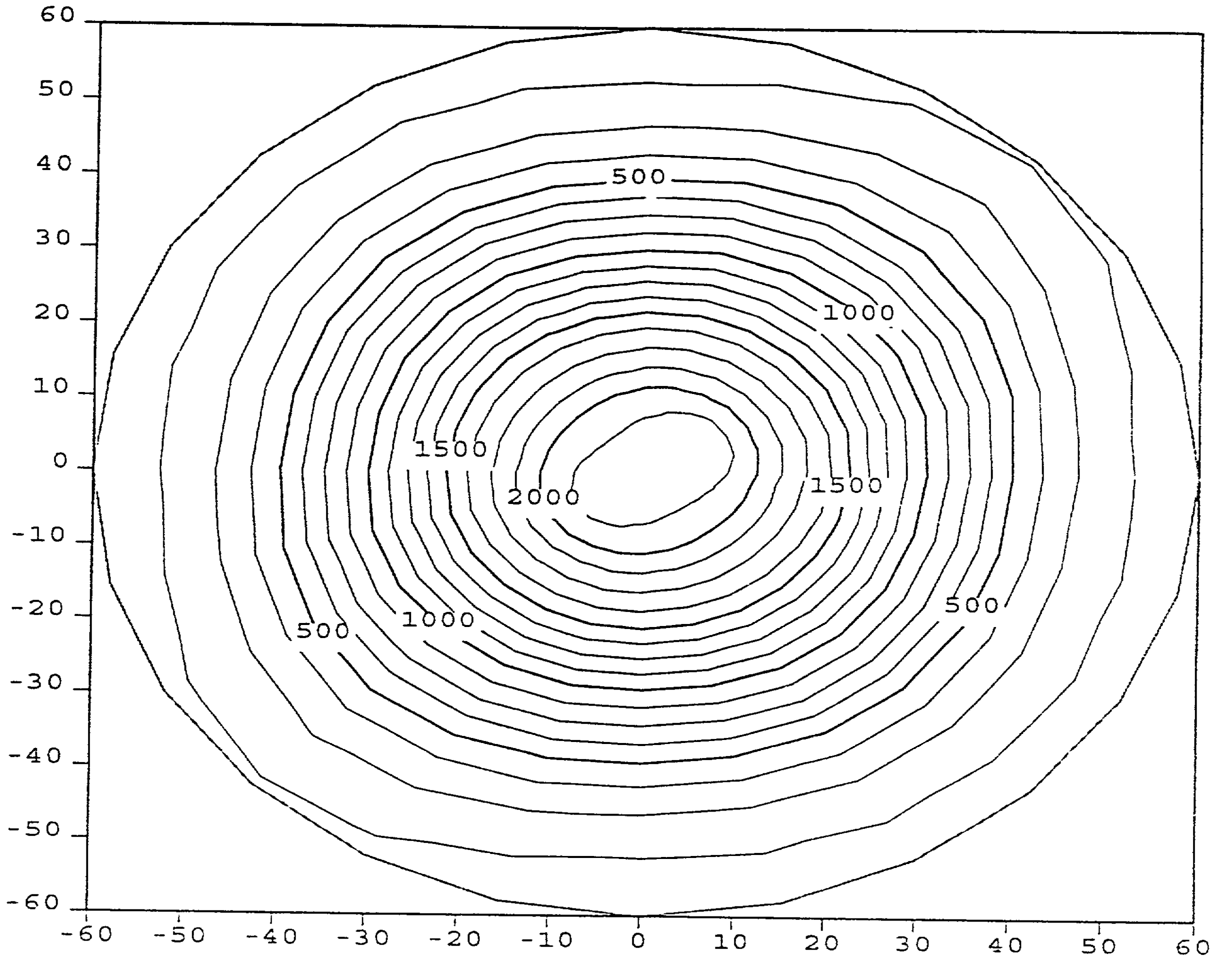

60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60
500
1000
1500
2000
1500
1000
500
500

FIG. 12

PRINT OF DRAWINGS
AS ORIGINALLY FILED

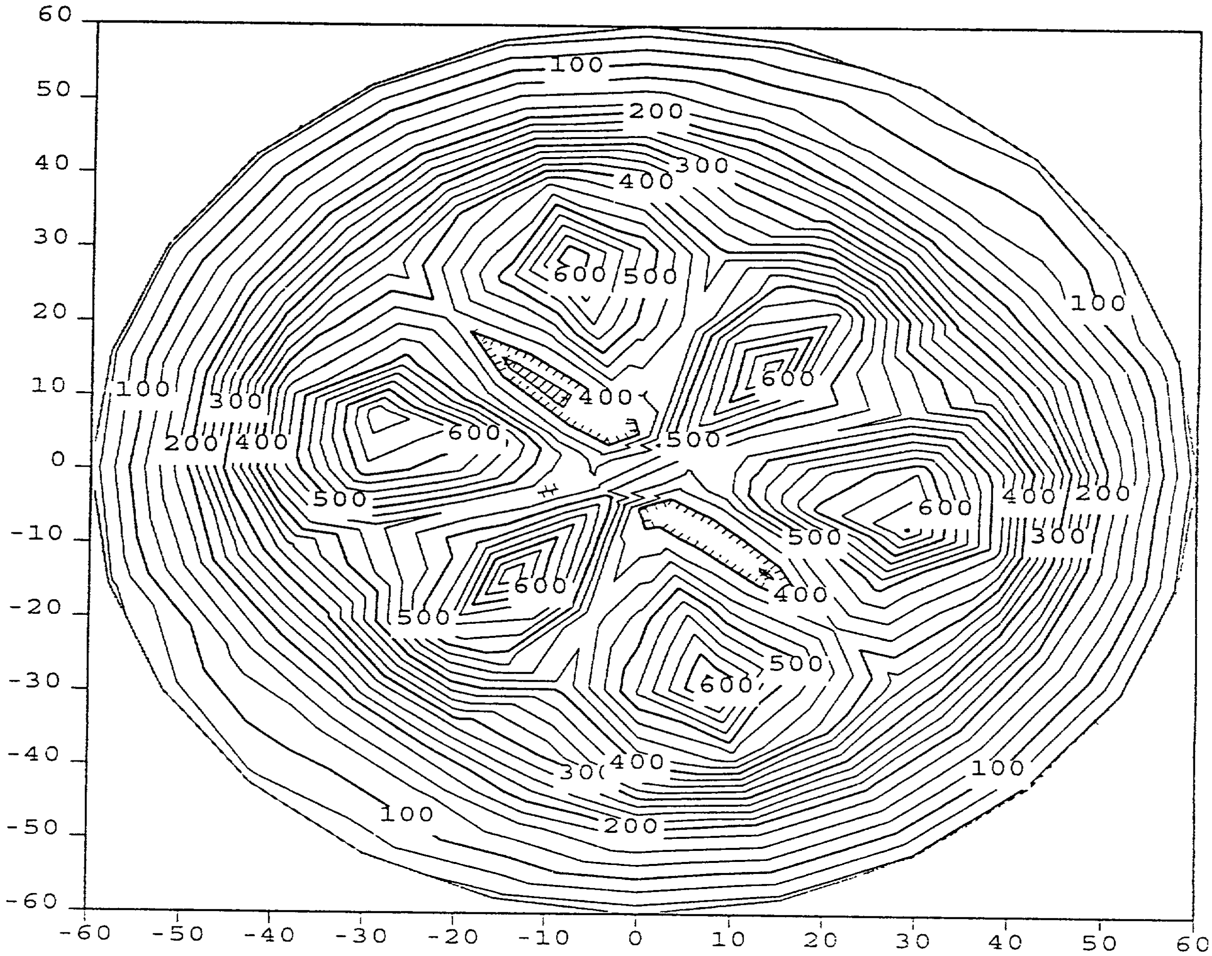


FIG. 13

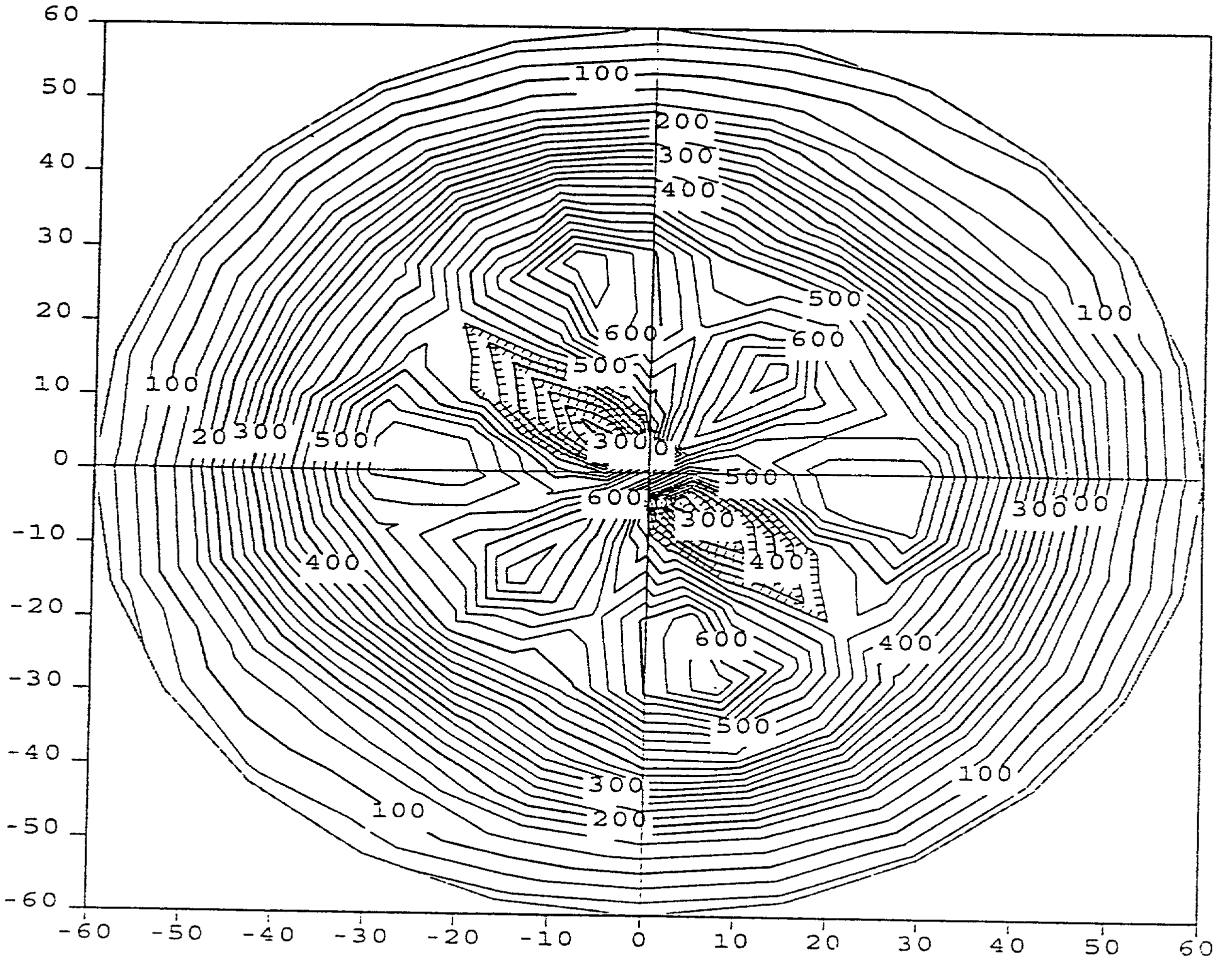

60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
100
200
300
400
500
600

FIG. 14

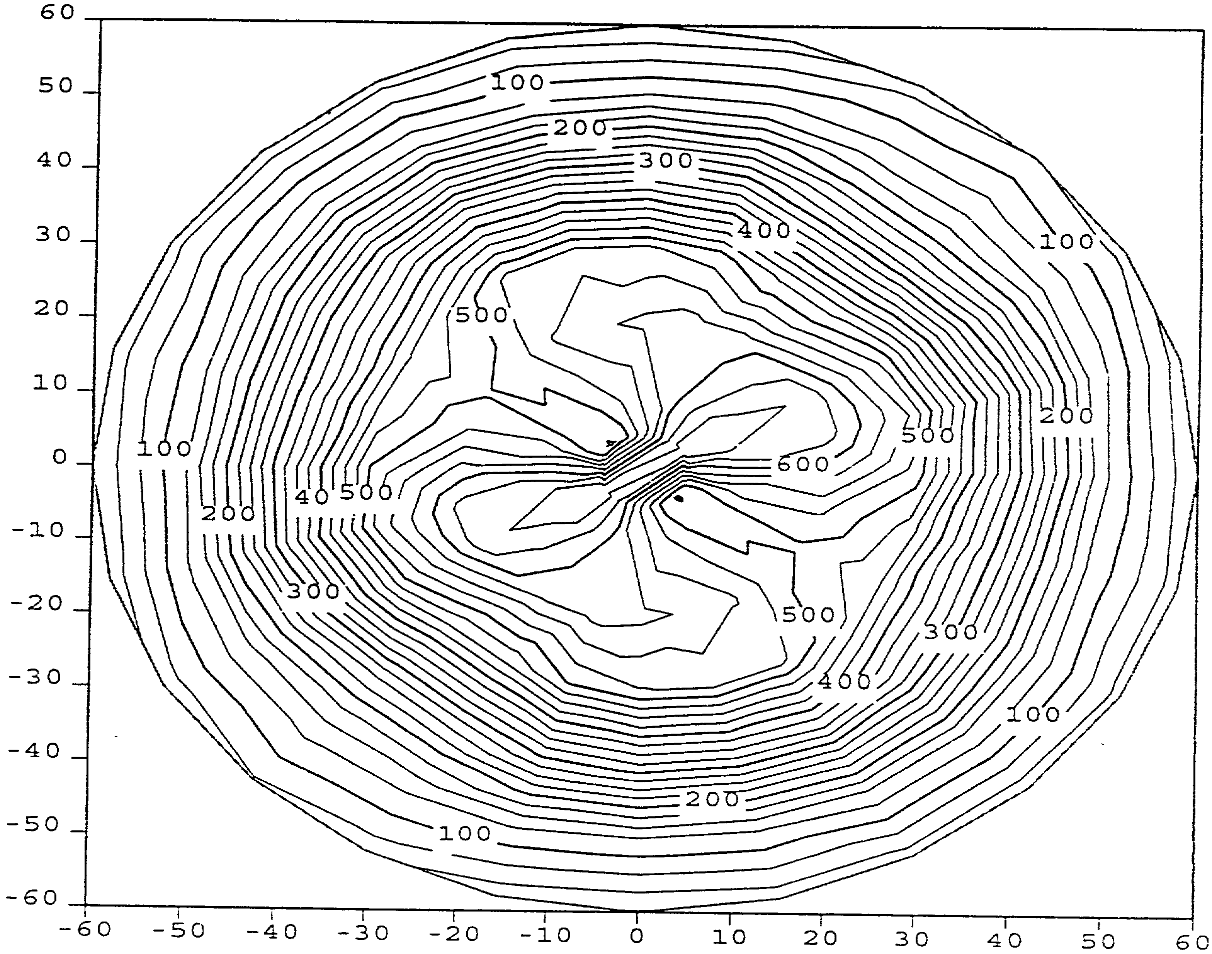

60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
100
200
300
400
500
600
100
200
40
500
300
500
300
400
100
200
100
200
500
100

FIG. 15

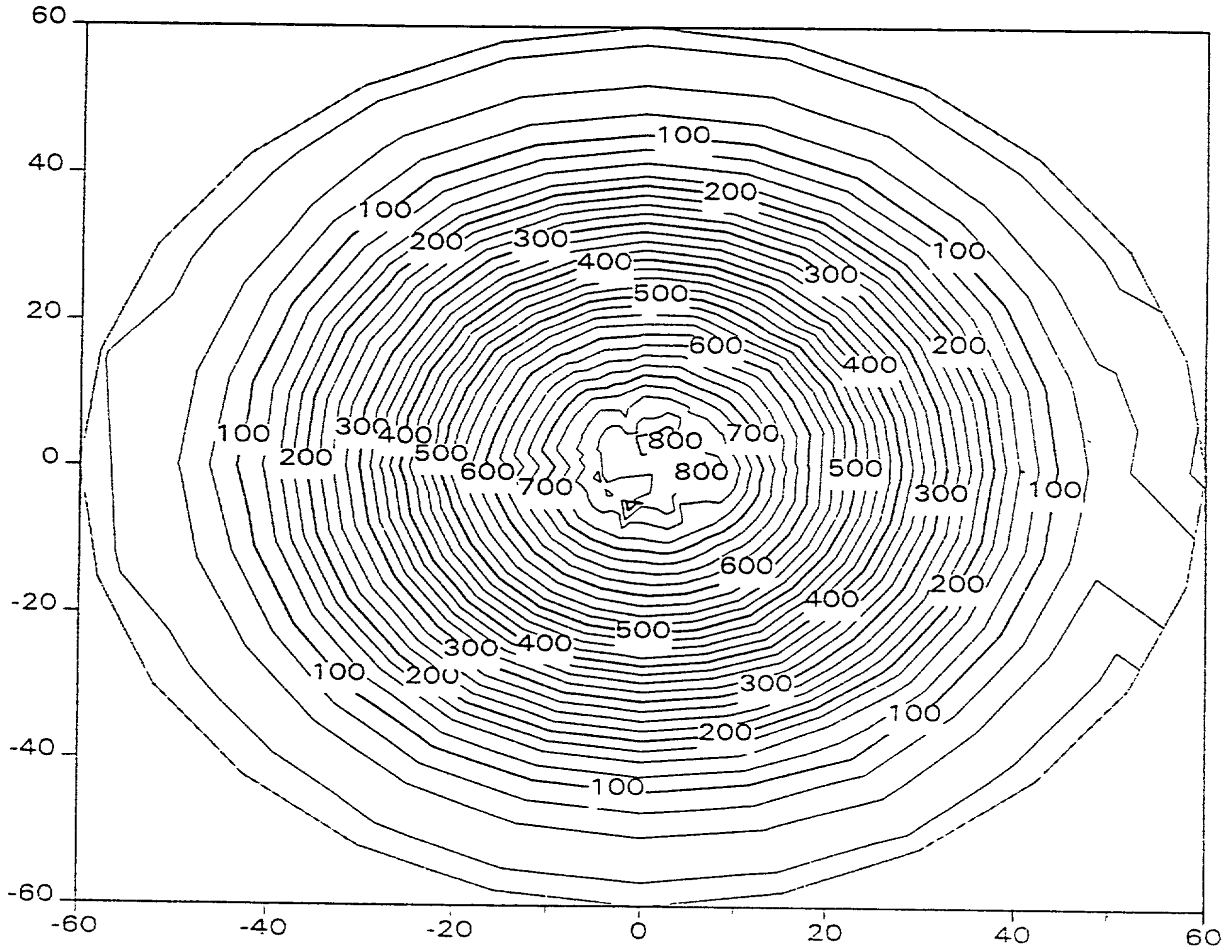

60
40
20
0
-20
-40
-60
-60
-40
-20
0
20
40
60
100
200
300
400
500
600
700
800

FIG. 16

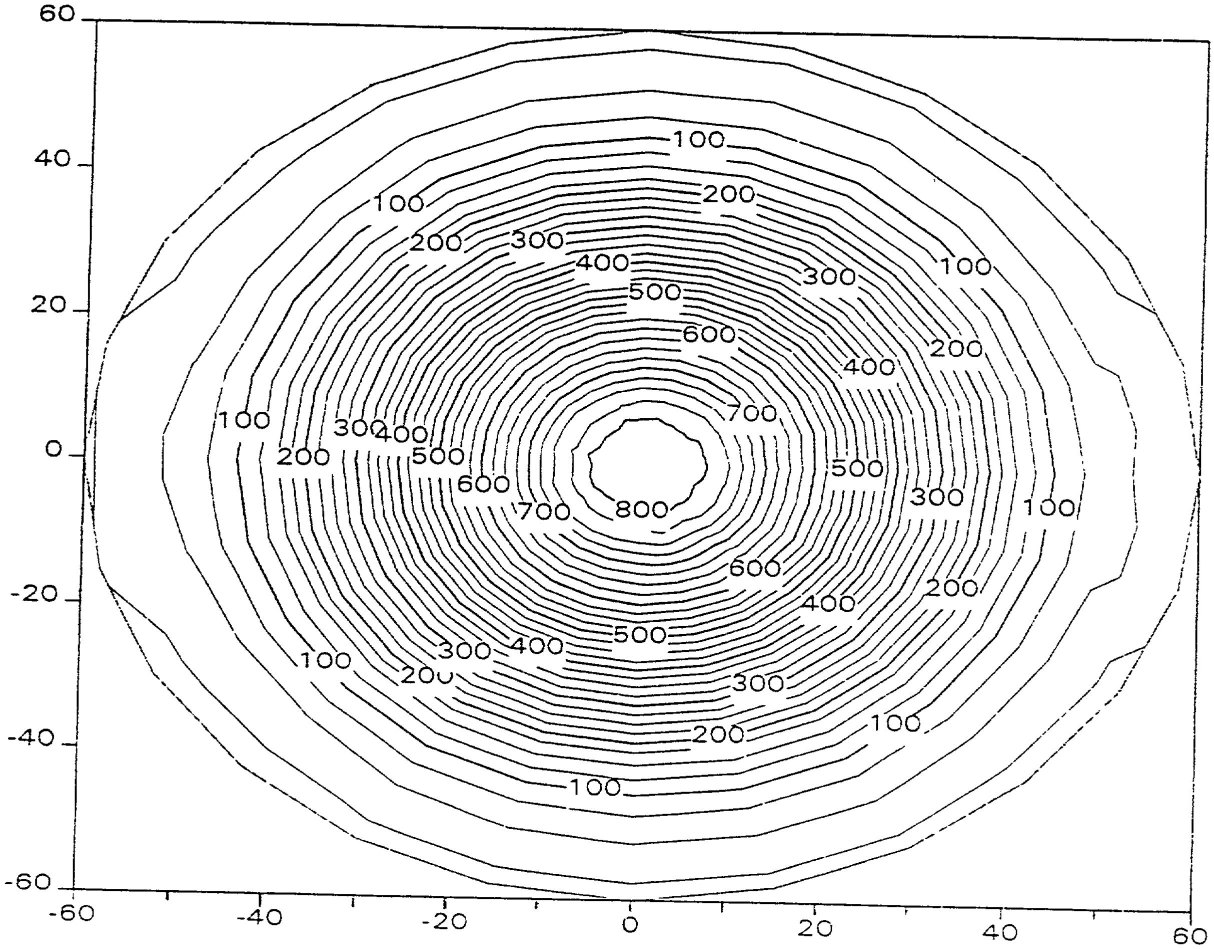

60
40
20
0
-20
-40
-60
-60
-40
-20
0
20
40
60
100
200
300
400
500
600
700
800

FIG. 17

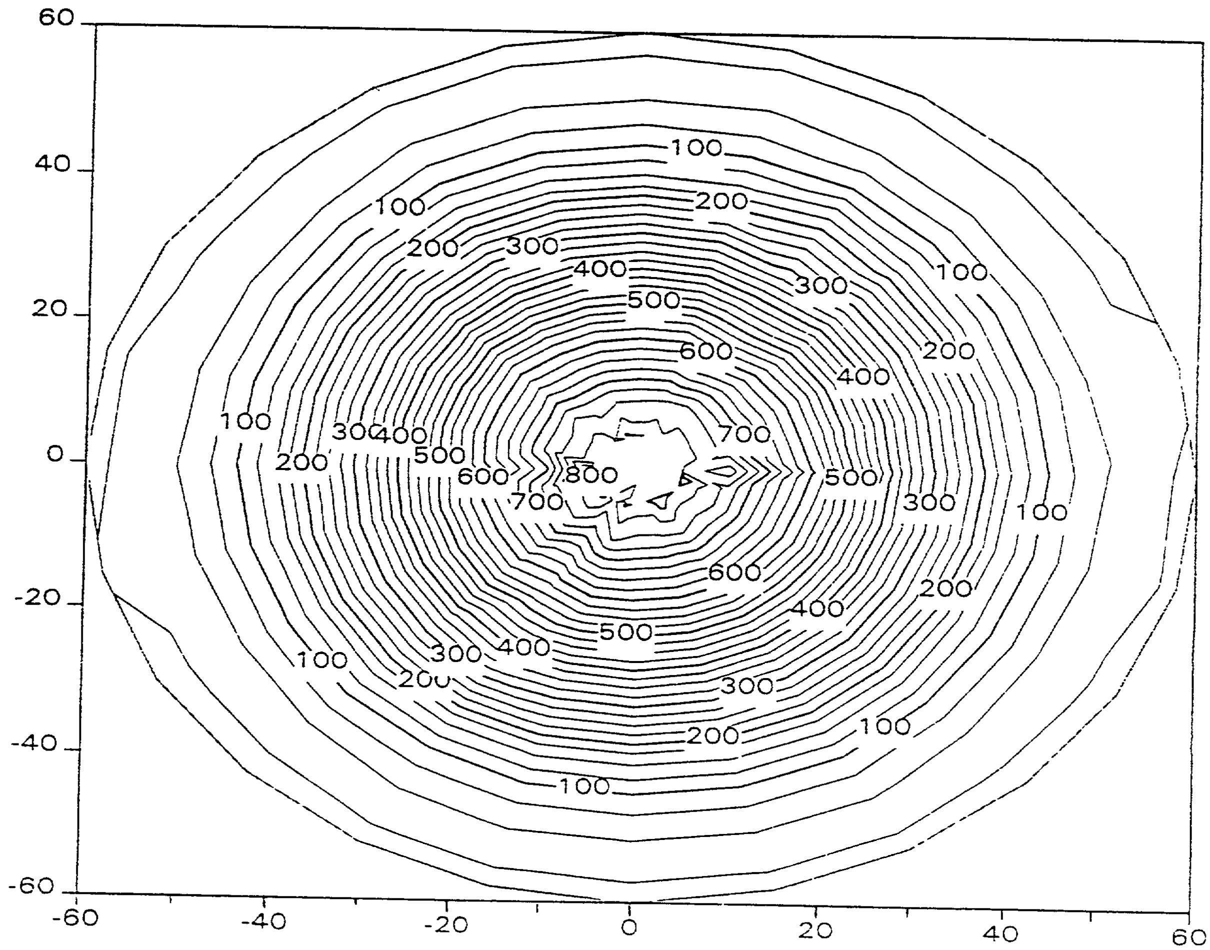

60
40
20
0
-20
-40
-60
-60
-40
-20
0
20
40
60
100
200
300
400
500
600
700
800

FIG. 18

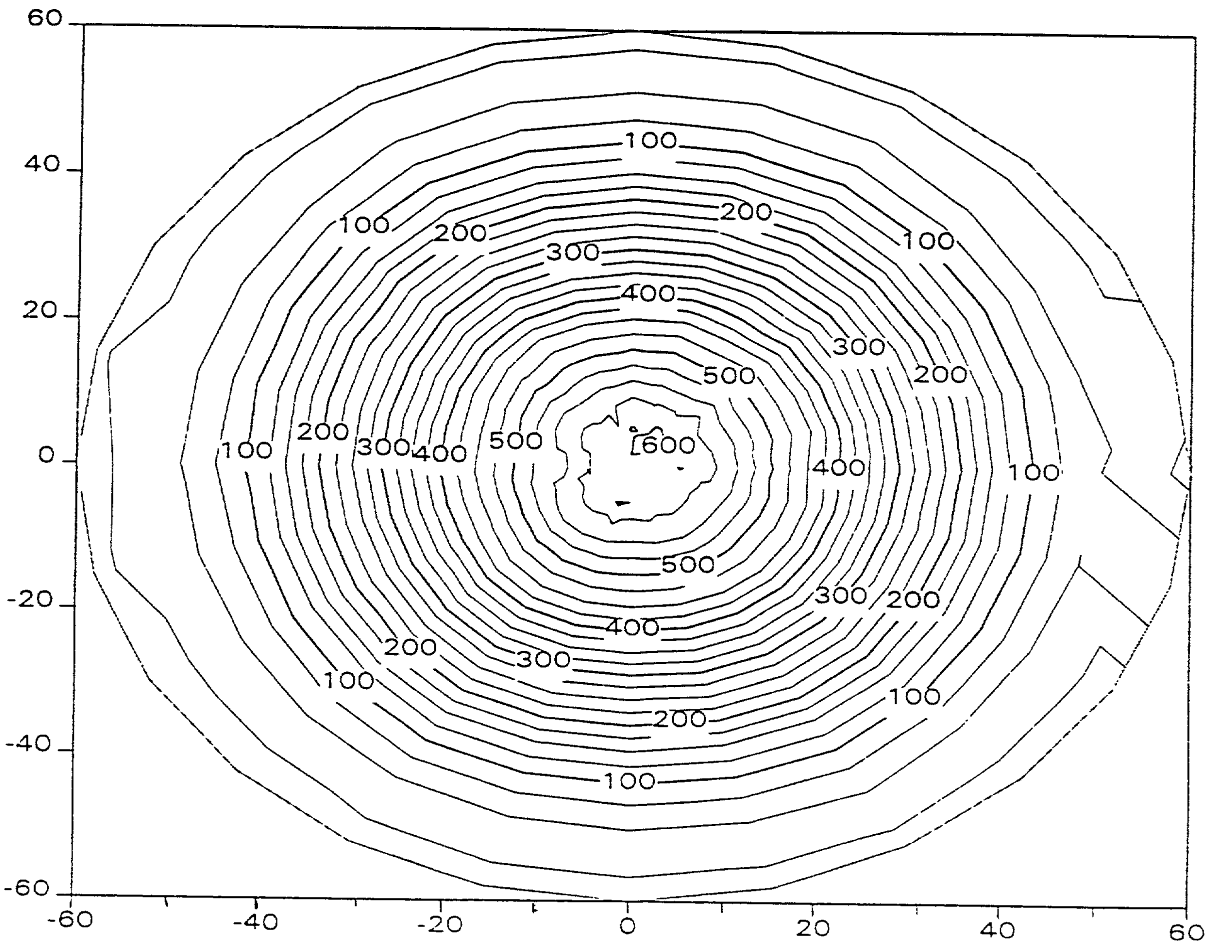


FIG. 19

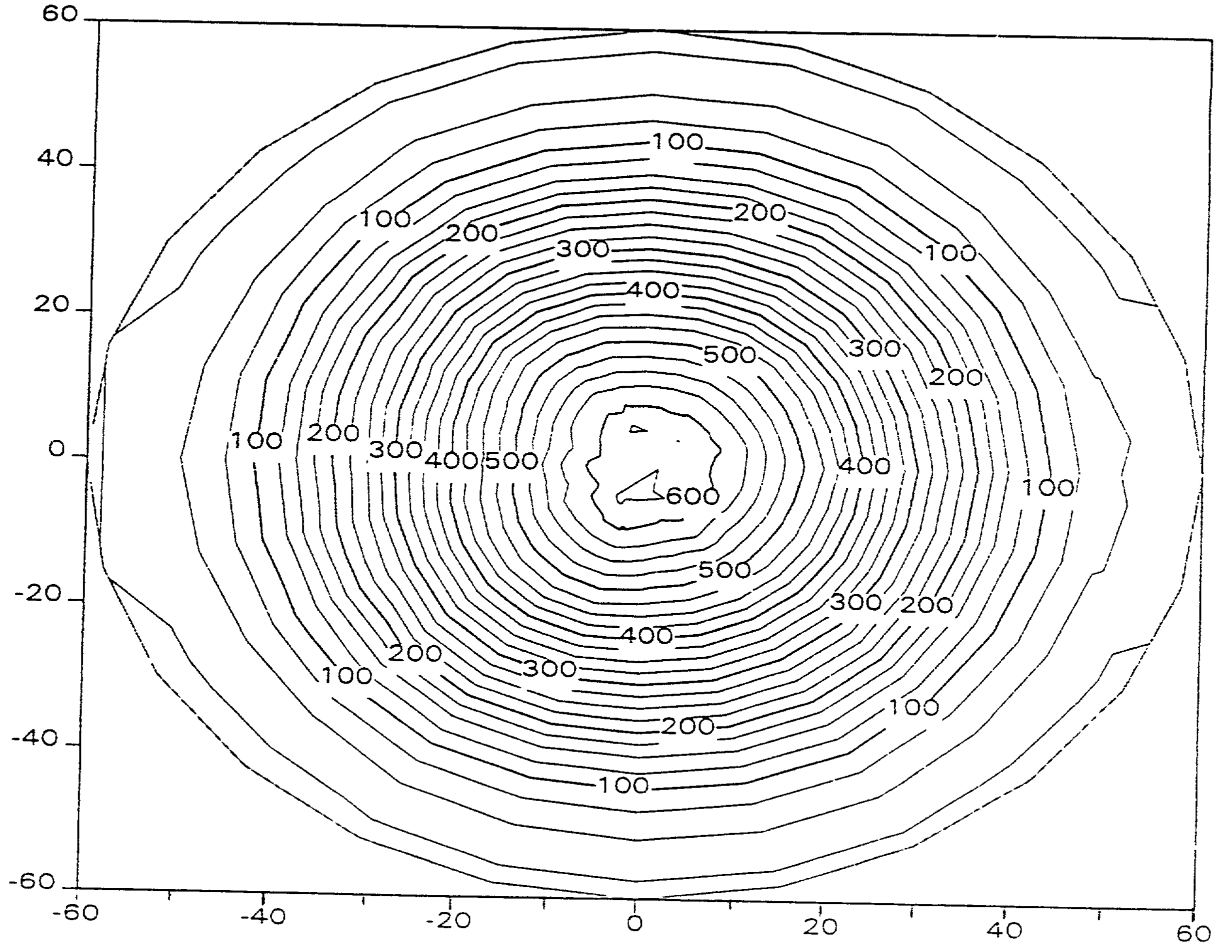


FIG. 20

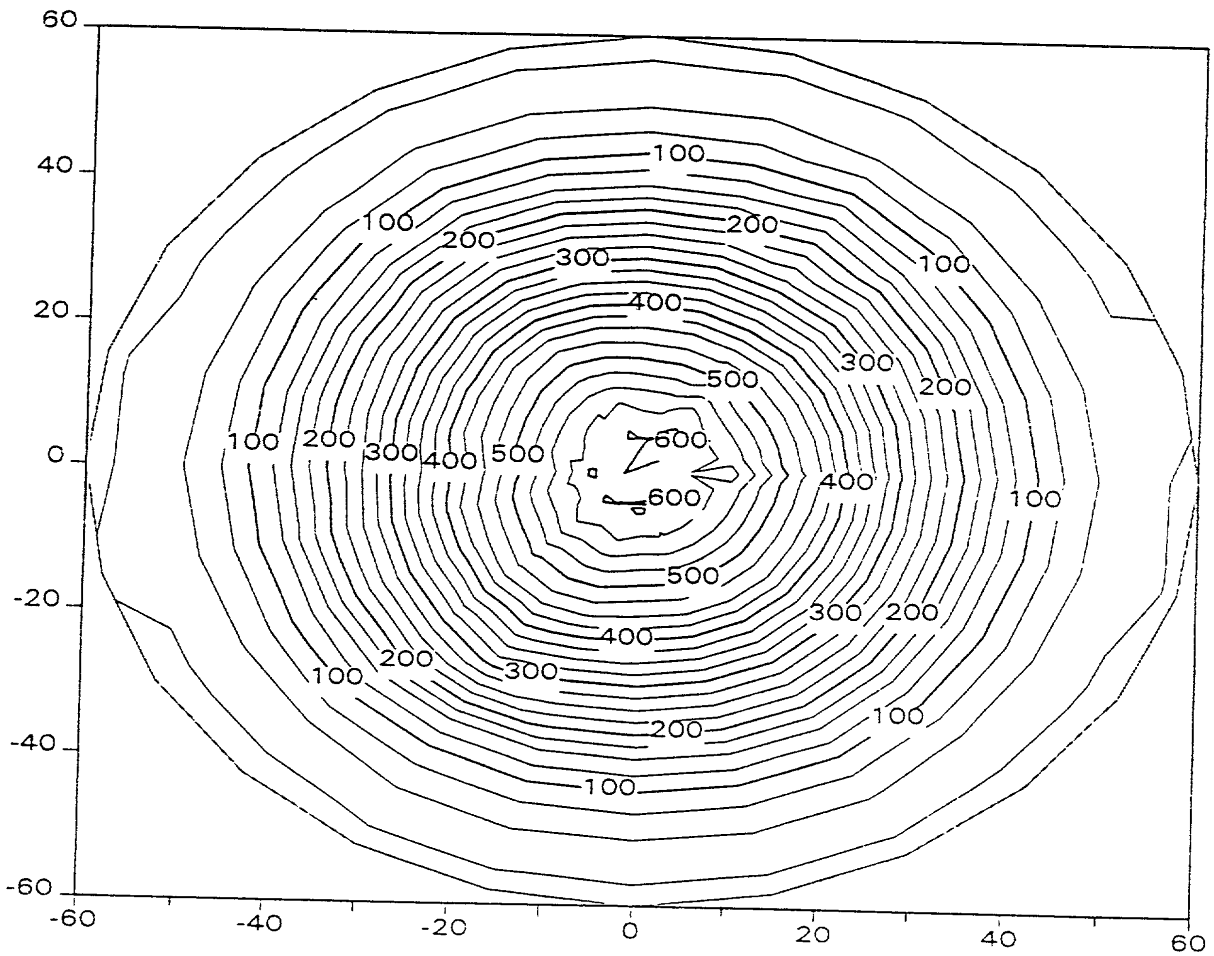


FIG. 21

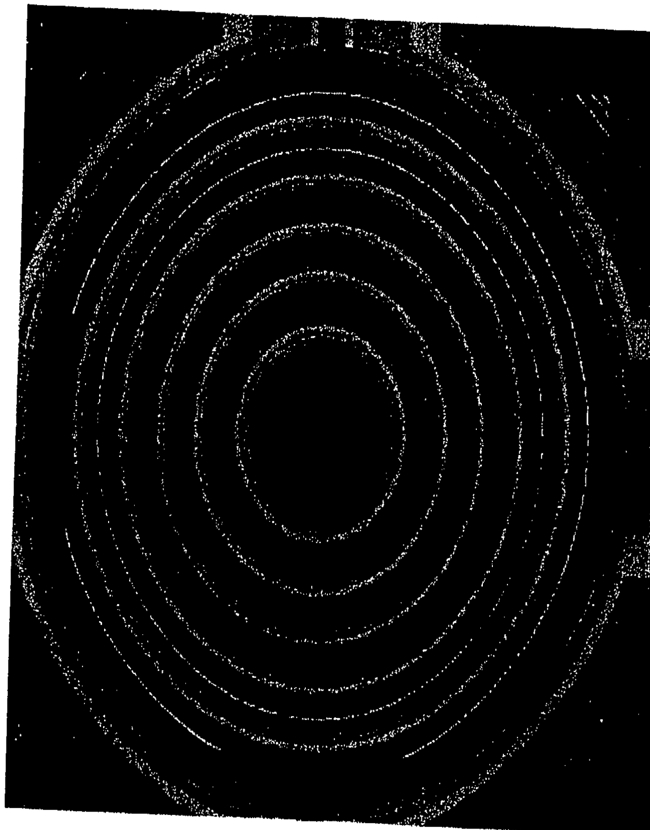


FIG. 22A

Diffraction Pattern
p=2/1000"
Angles: 5, 0

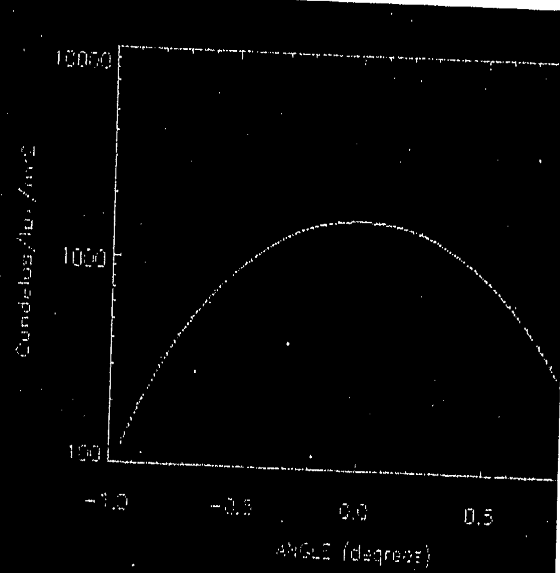


FIG. 22B

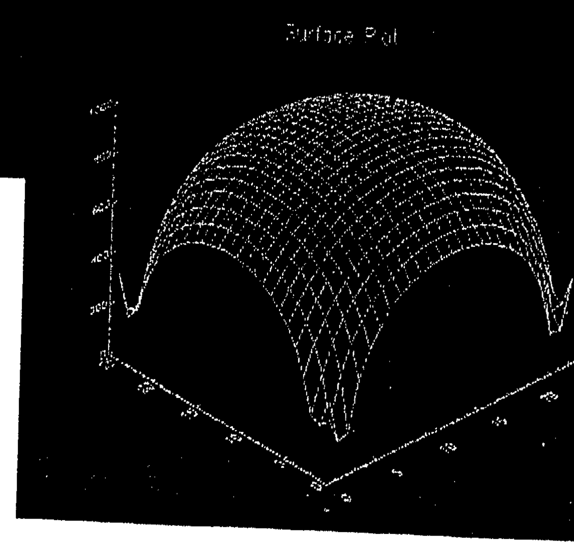


FIG. 22C

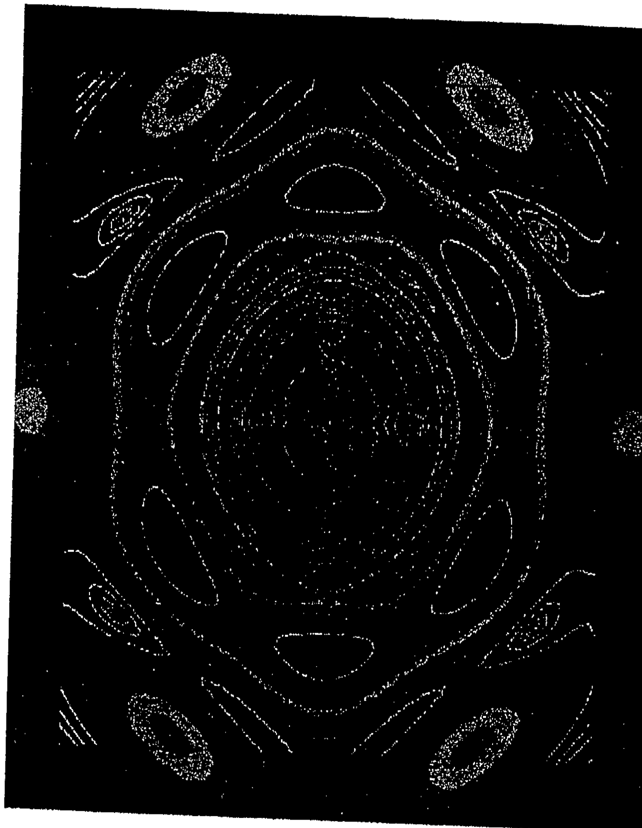


FIG. 23A

Diffraction pattern
p 6/1000"
Angles 5. 0

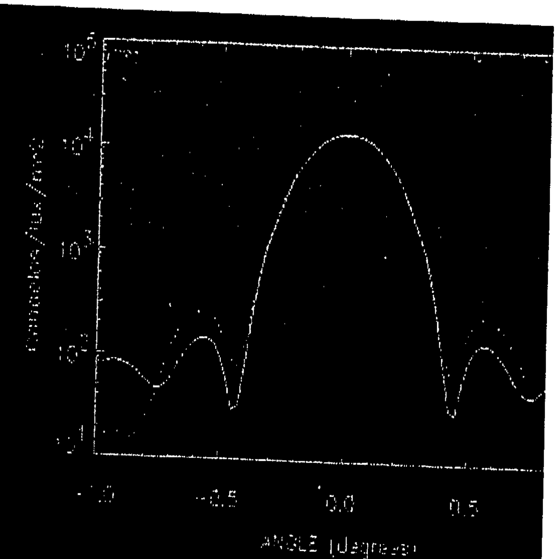


FIG. 23B

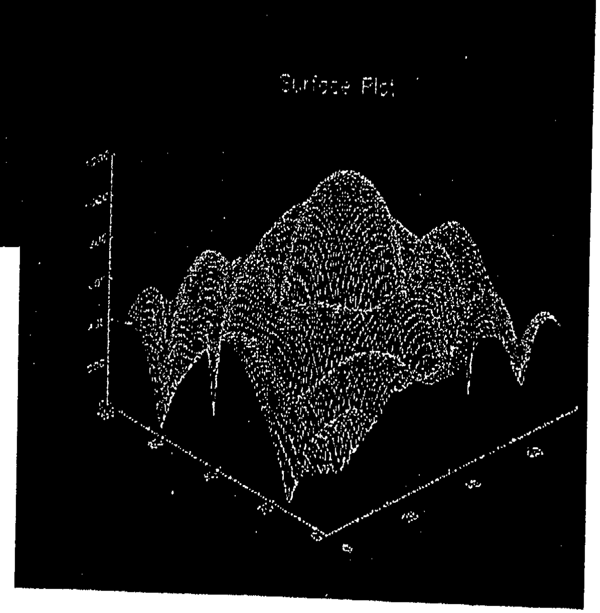
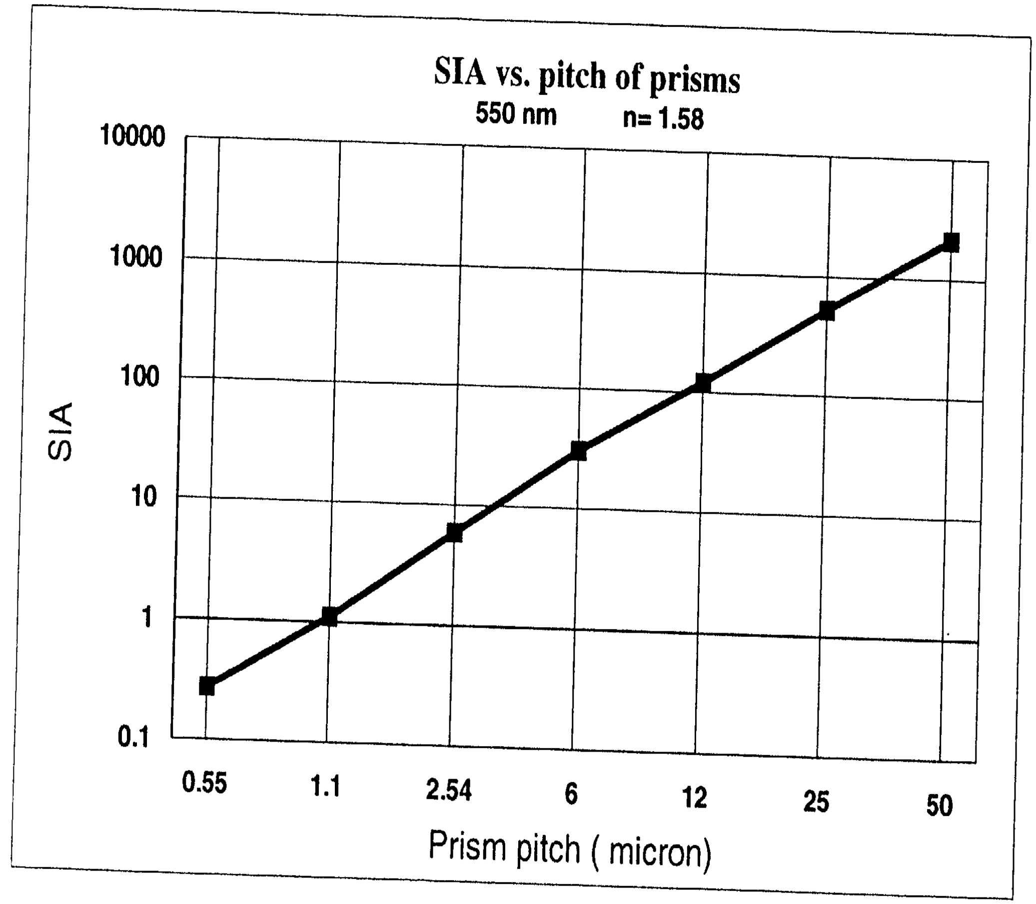


FIG. 23C



p	0.55	1.1	2.54	6	12	25	50
SIA(center)	0.277	1.11	5.92	30.67	122.68	532.48	2113.43

FIG. 24

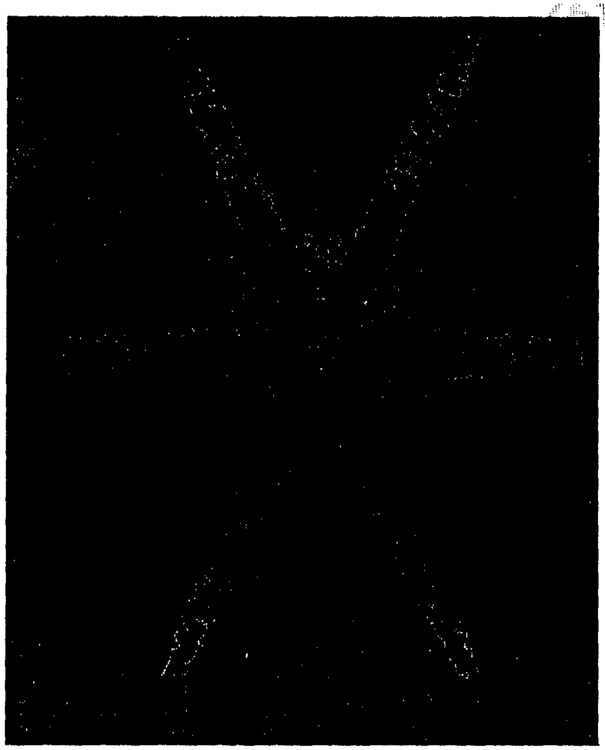


FIG. 25A

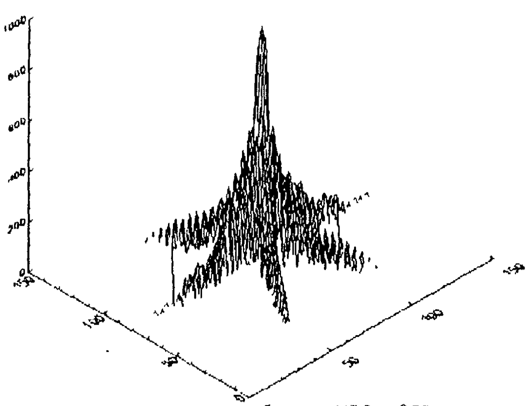
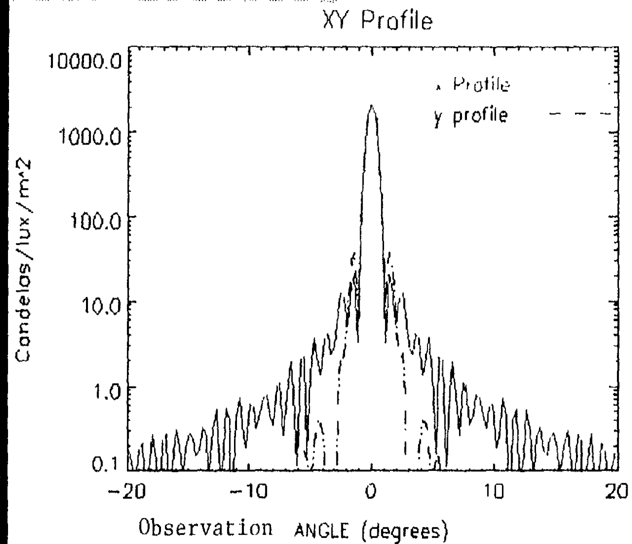
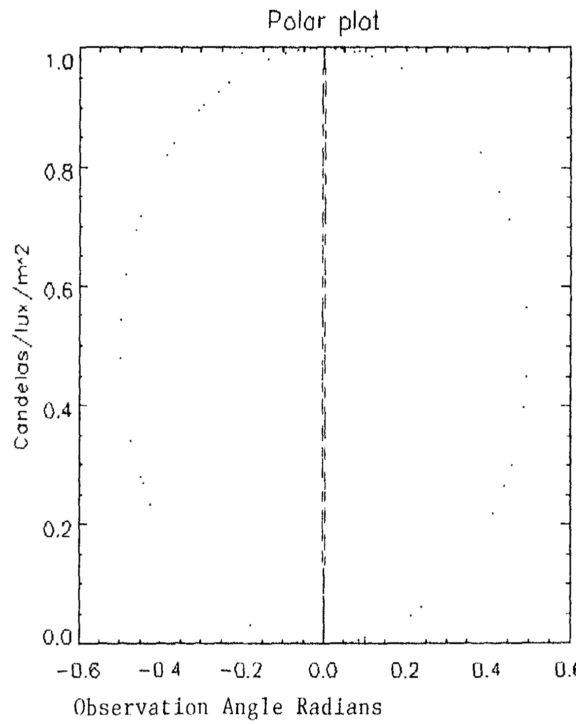


FIG. 25B



p = 2 mil

FIG. 25C



550 nm

FIG. 25D

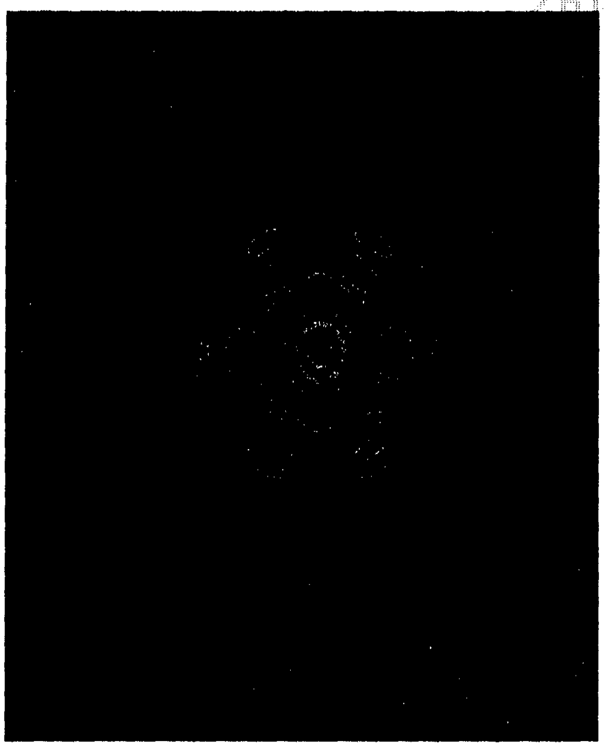


FIG. 26A

Surface Plot

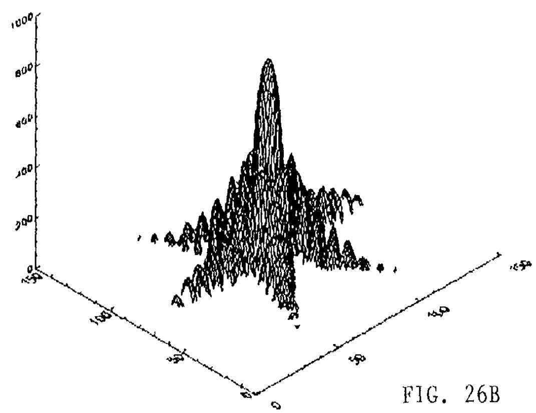
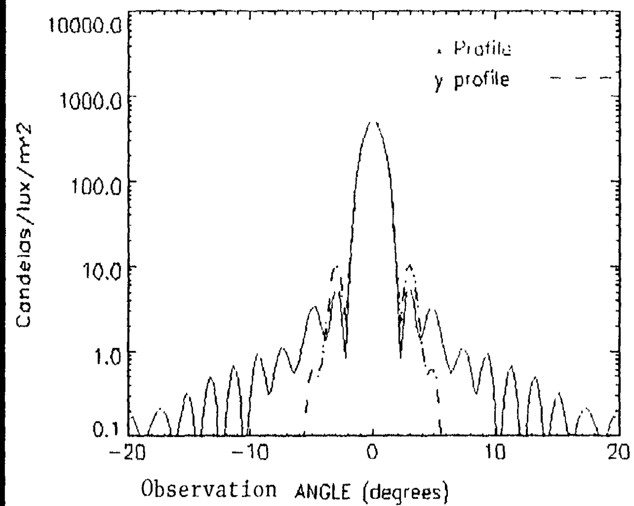


FIG. 26B

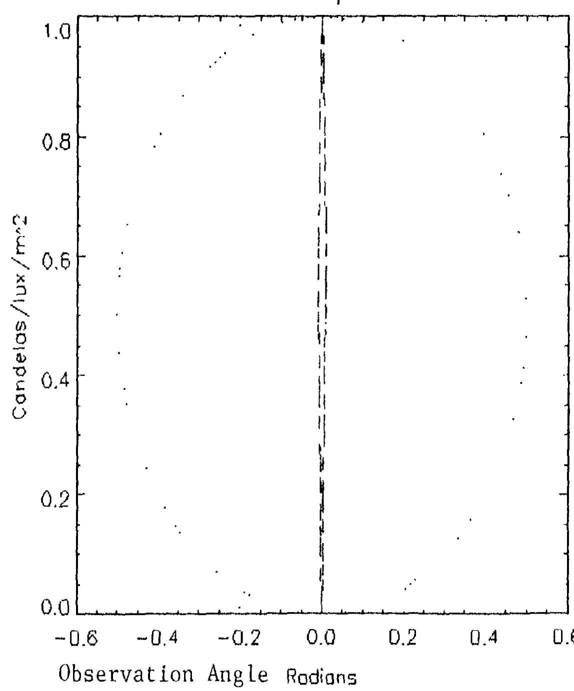
XY Profile



p=1mil

FIG. 26C

Polar plot



550 nm

FIG. 26D

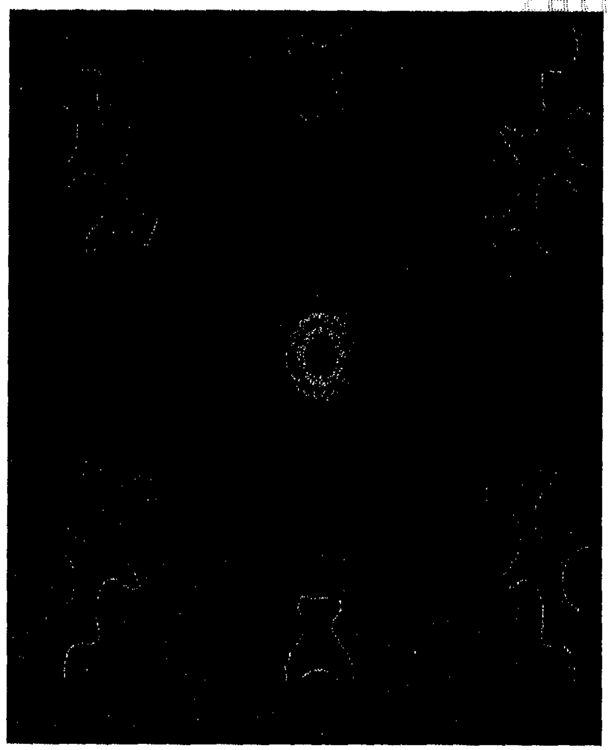


FIG. 27A

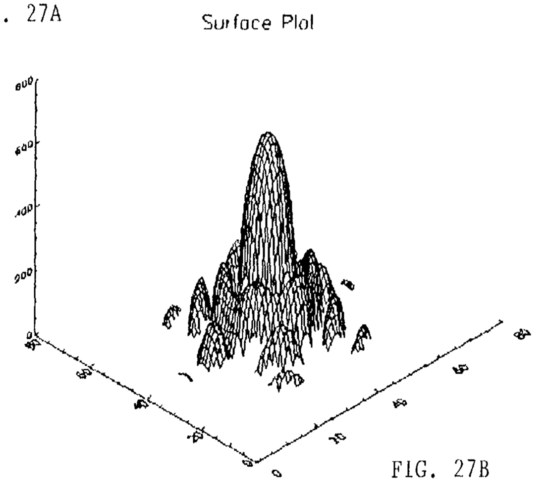
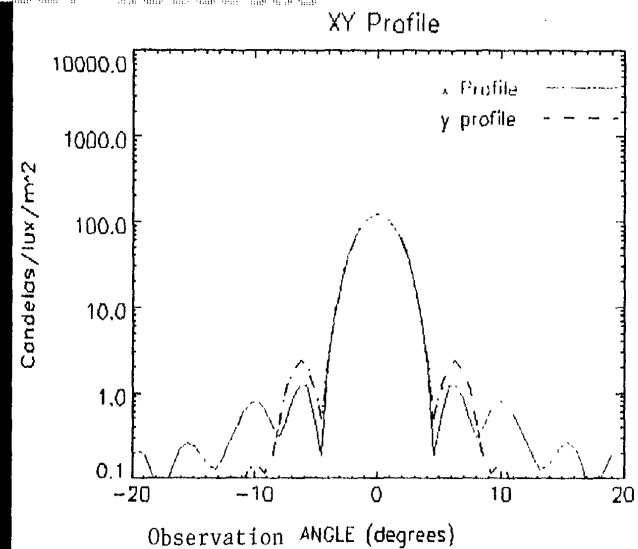
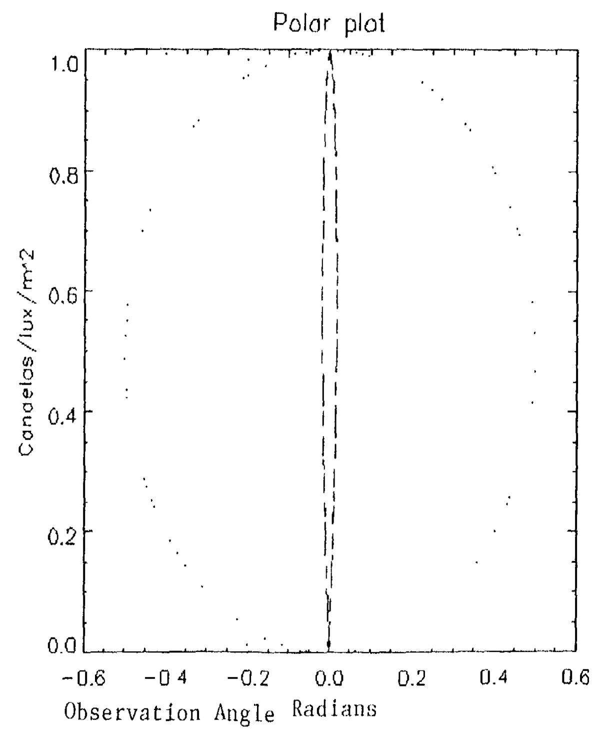


FIG. 27B



p = .5 mil,

FIG. 27C



550 nm

FIG. 27D

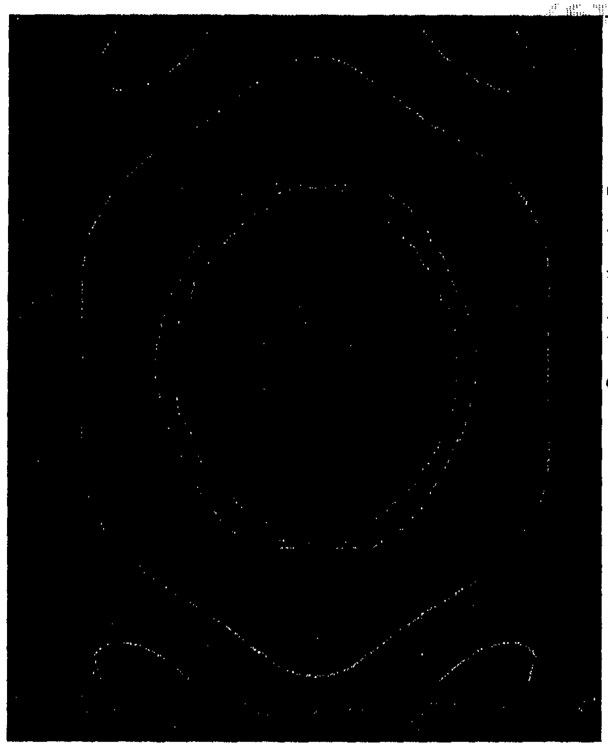


FIG. 28A

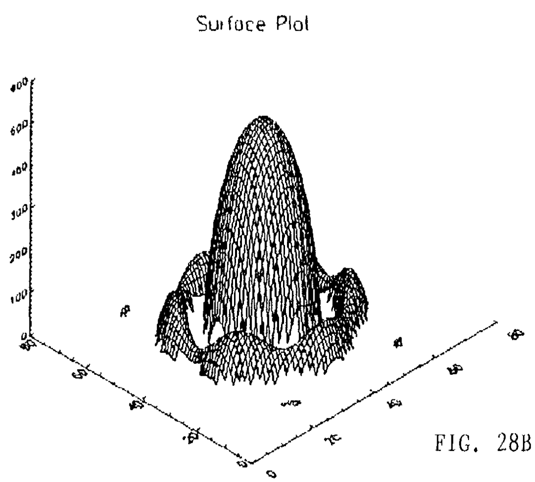
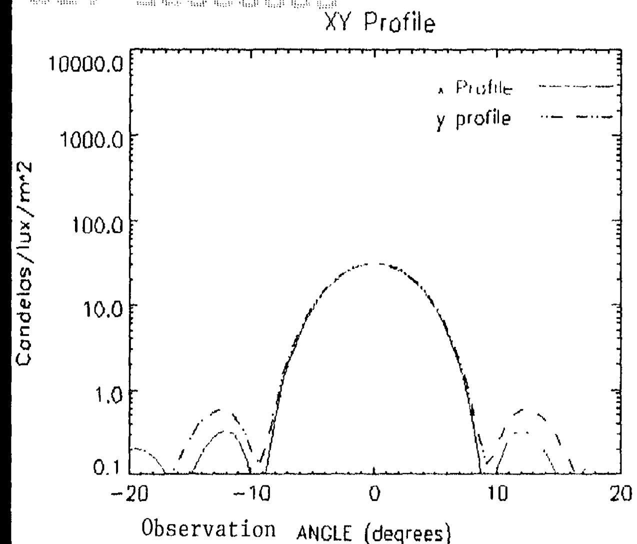


FIG. 28B



p = .24 mil

FIG. 28C

550 nm

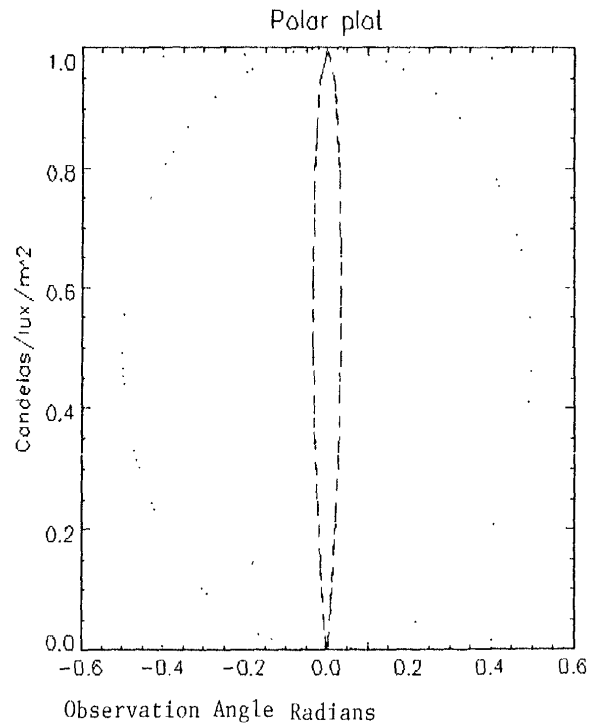


FIG. 28D

PRINT OF DRAWINGS AS ORIGINALLY FILED

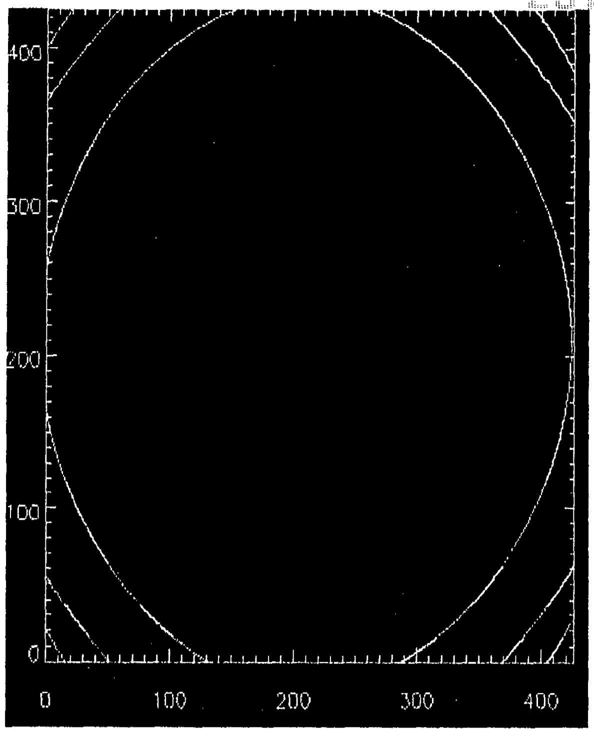


FIG. 29A

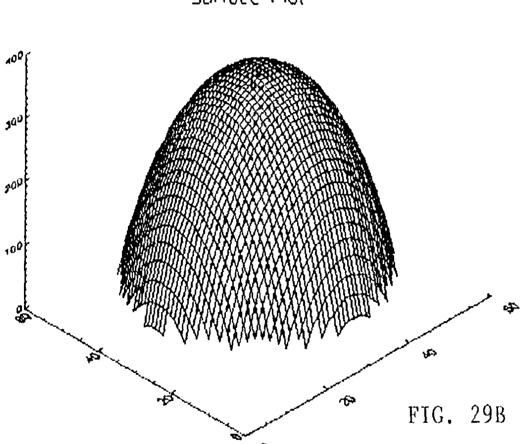
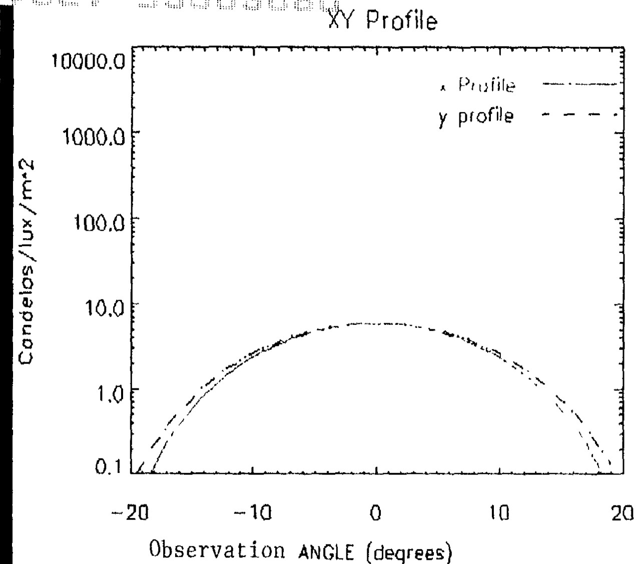


FIG. 29B



p = .1mil

FIG. 29C

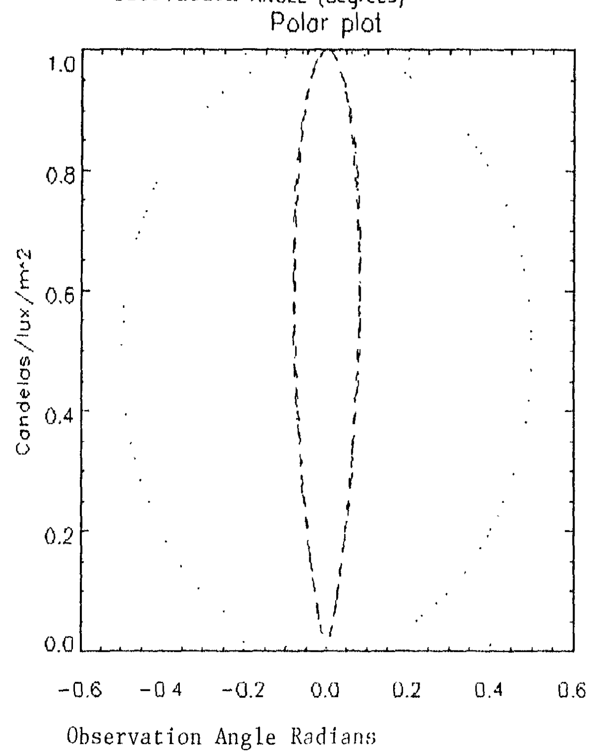


FIG. 29D

550nm

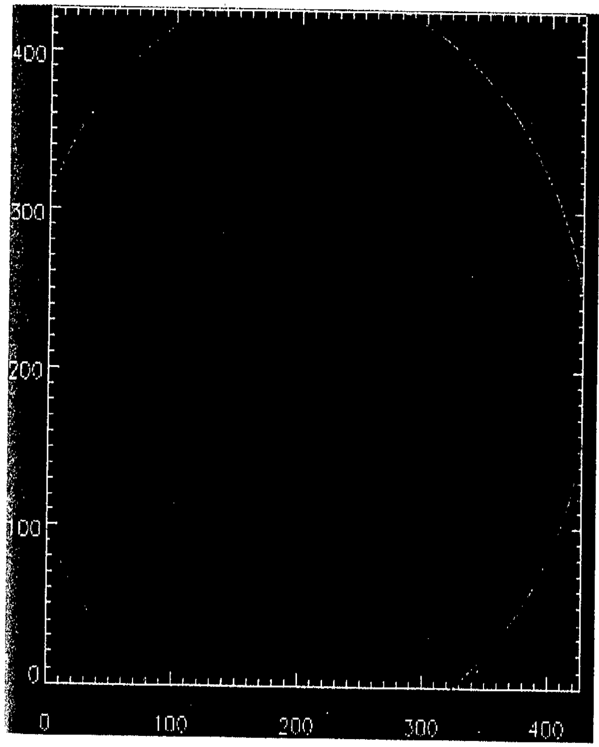


FIG. 30A

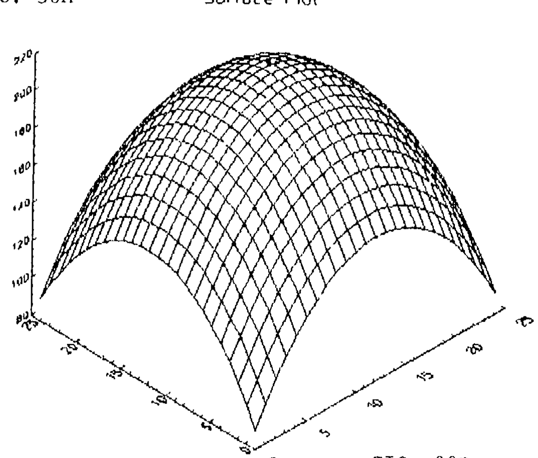


FIG. 30B

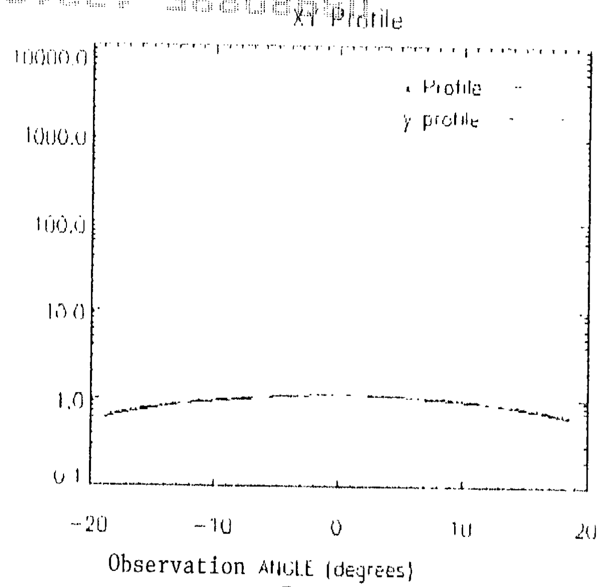


FIG. 30C

p = 2x550nm

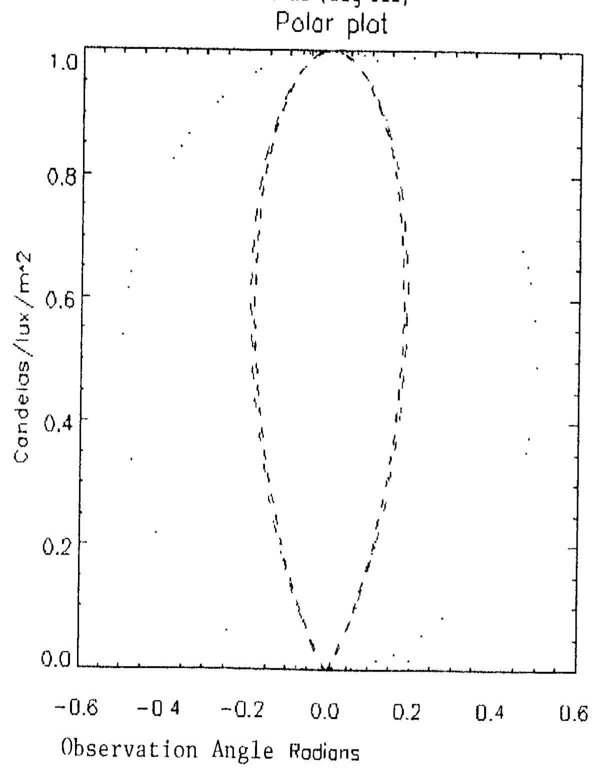


FIG. 30D

550 nm

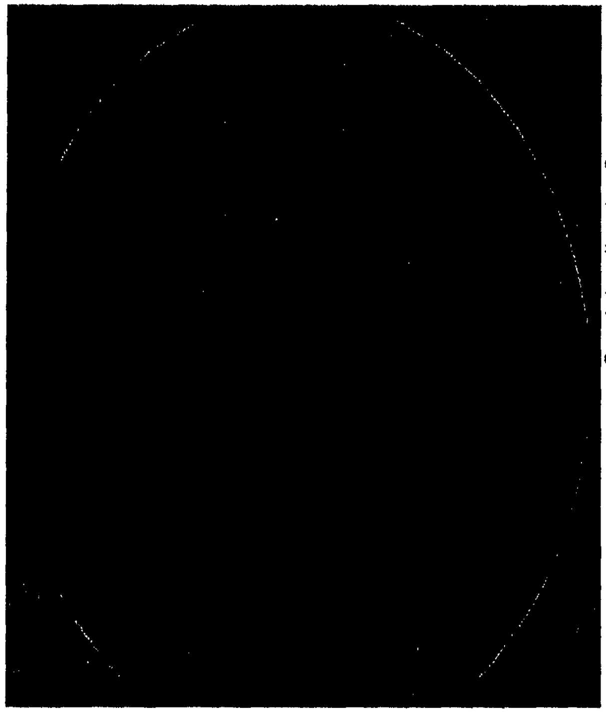


FIG. 31A

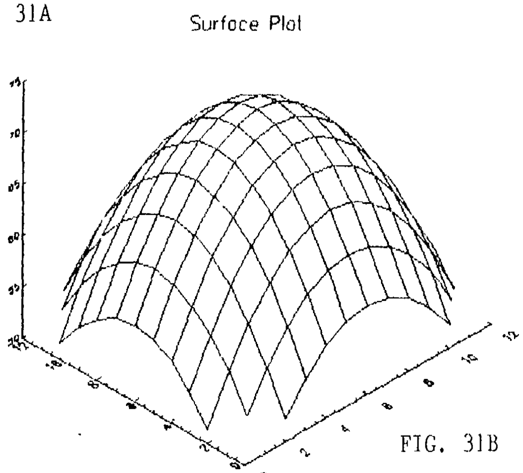


FIG. 31B

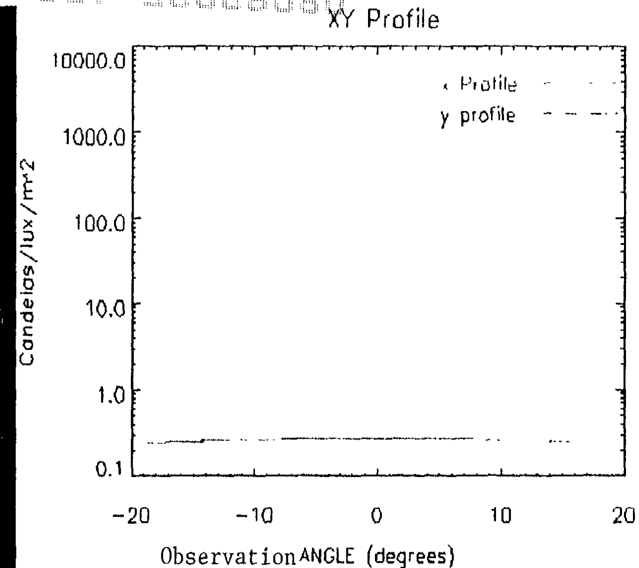


FIG. 31C

P=550 nm

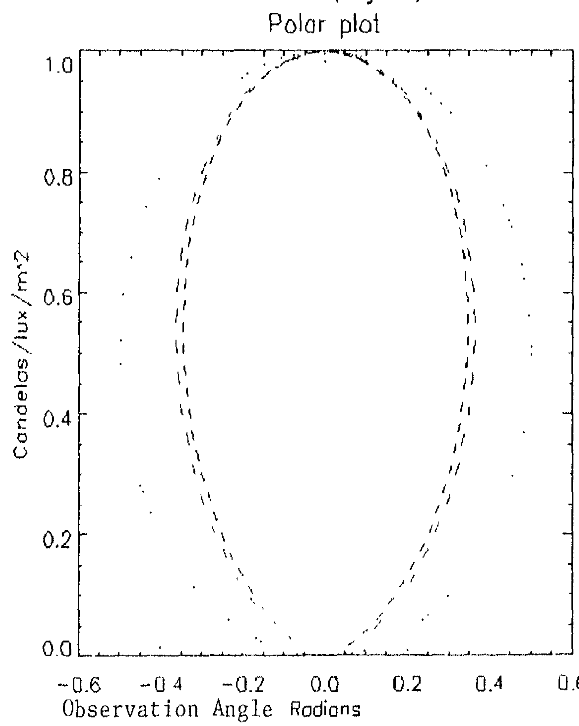


FIG. 31D

550 nm

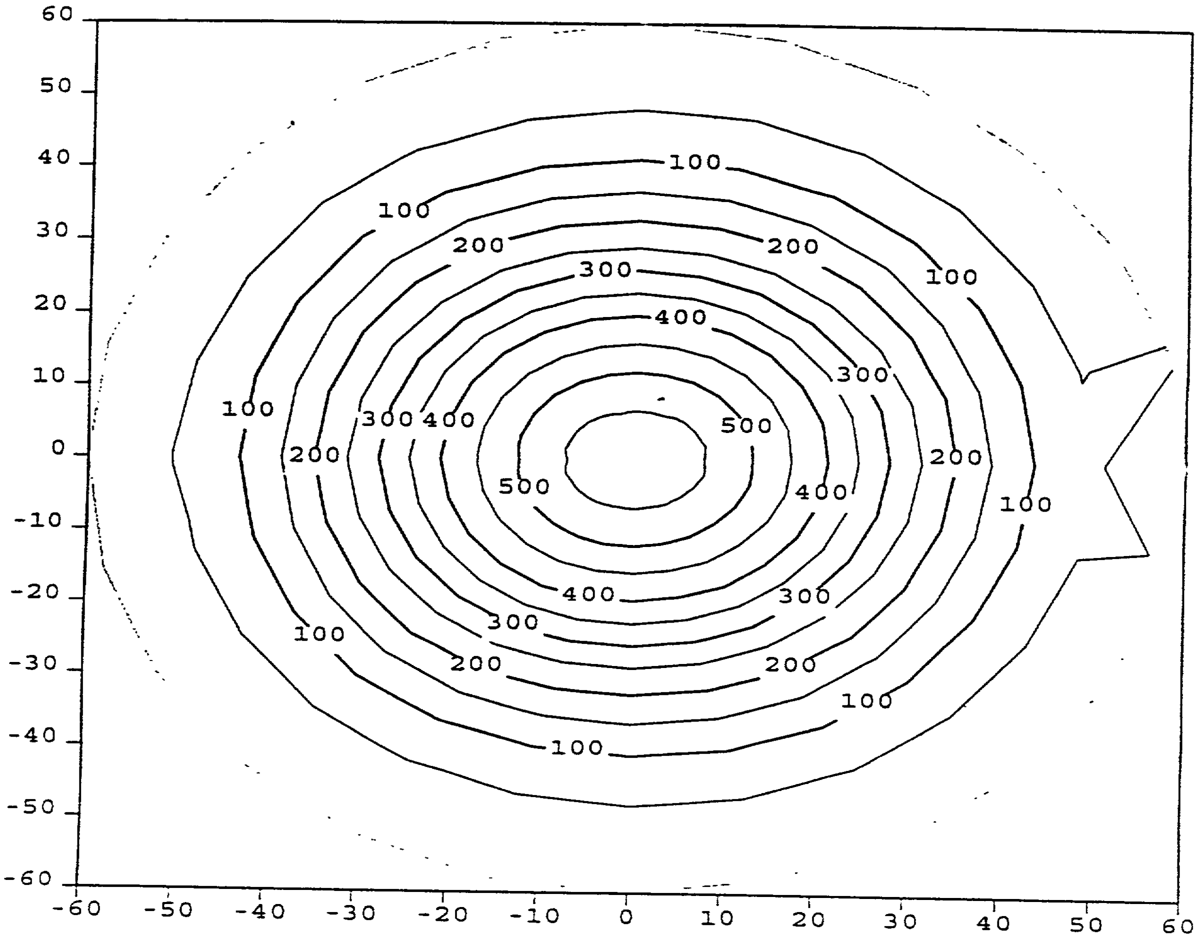

60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60
100
200
300
400
500

FIG. 32

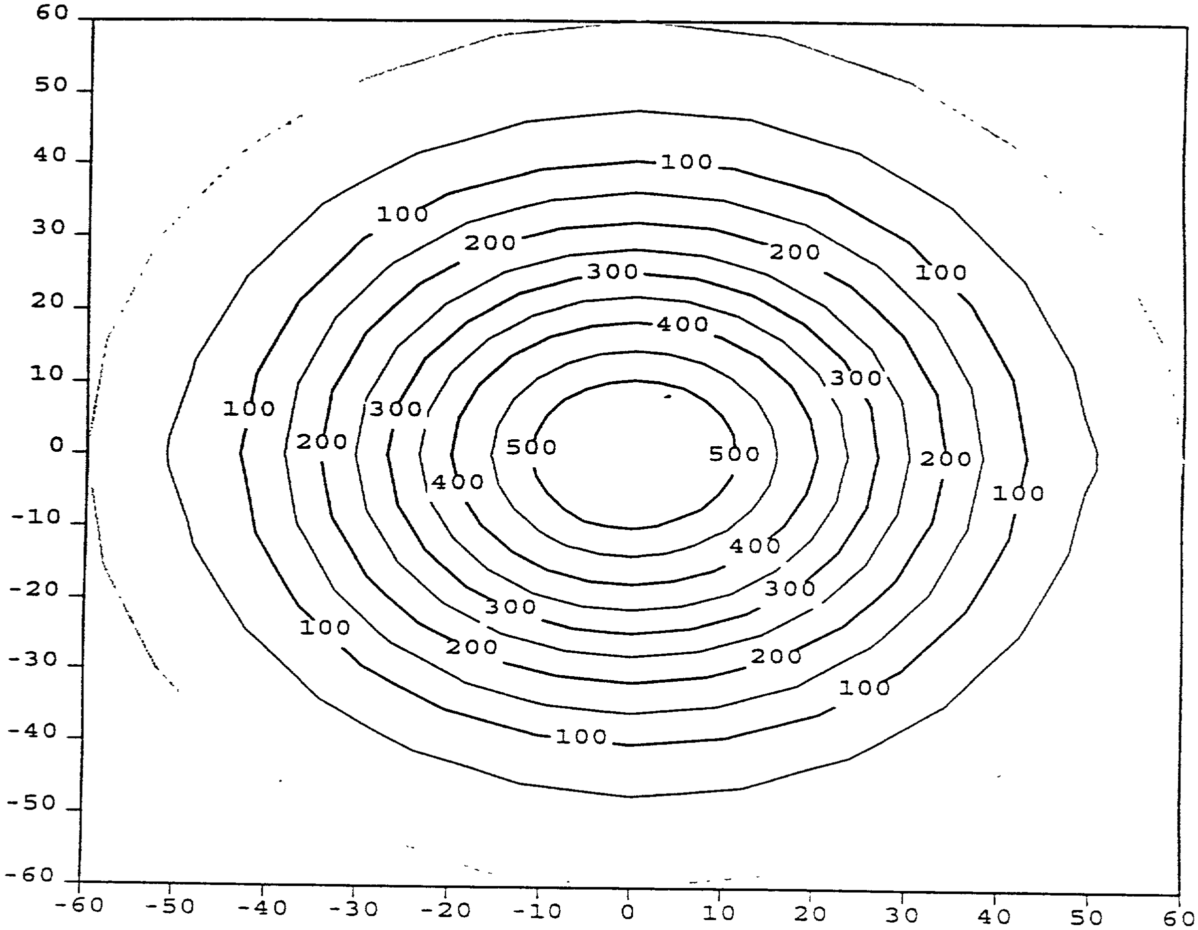

60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60
100
200
300
400
500

FIG. 33

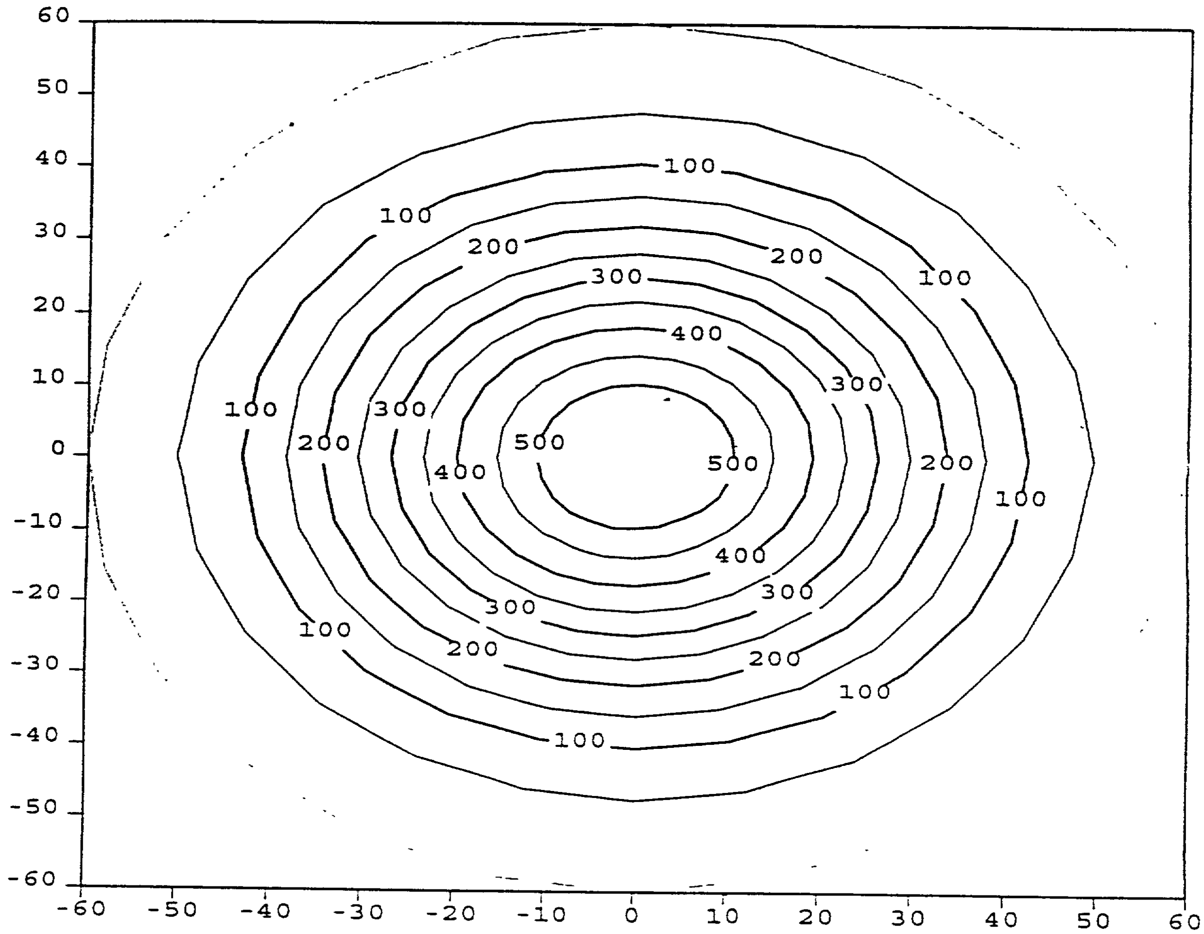

60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
100
200
300
400
500
500
400
300
200
100

FIG. 34

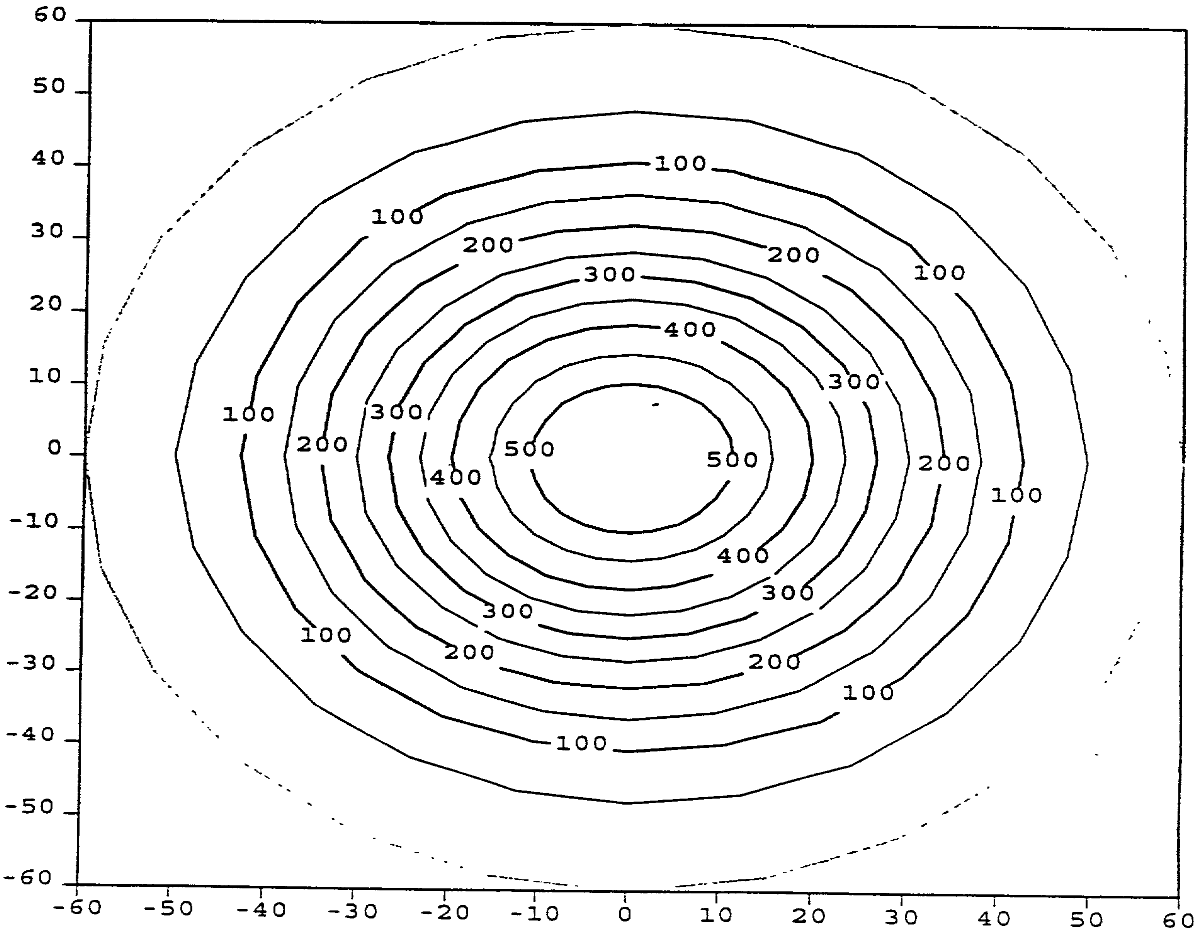

60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
100
200
300
400
500

FIG. 35

#3

DOCKET NO. RFX-349

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Declaration for Patent Application

As a named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated next to my name;

I believe I am the original, first and sole inventor (if only one name is listed) or an original, first and joint inventor (if plural names are listed in the signatory page(s) commencing at page 3 hereof) of the subject matter which is claimed and for which a patent is sought on the invention entitled

MINIATURE MICRO PRISM RETROREFLECTOR

the specification of which (check one)

[ ] is attached hereto.

[X] was filed on December 1, 1997 as United States Application Number or PCT International Application Serial No. 08/980,885 and was amended on ____________ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is known by me to be material to patentability as defined in 37 C.F.R. §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)			Priority Not Claimed
(Number)	(Country)	(Day/Month/Year filed)	[ ]
(Number)	(Country)	(Day/Month/Year filed)	[ ]
(Number)	(Country)	(Day/Month/Year filed)	[ ]

I hereby claim the benefit under 35 U.S.C. §119(e) of any United States provisional application(s) listed below.

(Application Number)	(Filing Date)
(Application Number)	(Filing Date)

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose information known by me to be material to patentability as defined in 37 C.F.R. §1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial No.)	(Filing date)	(Status: patented, pending, abandoned)
(Application Serial No.)	(Filing date)	(Status: patented, pending, abandoned)
(Application Serial No.)	(Filing date)	(Status: patented, pending, abandoned)
(Application Serial No.)	(Filing date)	(Status: patented, pending, abandoned)

As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

I also hereby grant additional Powers of Attorney to the following attorney(s) and/or agent(s) to file and prosecute an international application under the Patent Cooperation Treaty based upon the above-identified application, including a power to meet all designated office requirements for designated states:

David E. Brook	Reg. No. 22,592	Alice O. Carroll	Reg. No. 33,542
James M. Smith	Reg. No. 28,043	N. Scott Pierce	Reg. No. 34,900
Leo R. Reynolds	Reg. No. 20,884	Richard A. Wise	Reg. No. 18,041
Patricia Granahan	Reg. No. 32,227	Helen E. Wendler	Reg. No. 37,964
Mary Lou Wakimura	Reg. No. 31,804	Carolyn S. Elmore	Reg. No. 37,567
Thomas O. Hoover	Reg. No. 32,470		

all of Hamilton, Brook, Smith and Reynolds, P.C., Two Militia Drive, Lexington, Massachusetts 02173;

and ______________________________

Send correspondence to: Leo R. Reynolds, Esq.
Hamilton, Brook, Smith & Reynolds, P.C.
Two Militia Drive, Lexington, MA 02173

Direct telephone calls to: Leo R. Reynolds, Esq.
(781) 861-6240

Direct facsimiles to: Leo R. Reynolds, Esq.
(781) 861-9540

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of sole
or first inventor William P. Rowland

Inventor's
Signature William P Rowland Date Jan 27th 1998

Residence 1152 East Street
Southington, Connecticut 06489

Citizenship U.S. Citizen

Post Office Address Same as above

Full name of second joint
inventor, if any Robert B. Nilsen

Inventor's
Signature Robert B. Nilsen Date Jan 27, 1998

Residence 11 Aspenwood Drive RBN 1/27/98
RBN 1/27/98 Weatogue ~~Wheatogue~~, CT 06089

Citizenship U.S. Citizen

Post Office Address Same as above

K:\LREYNOLD\LRR43\RFX349.dec